PRICE TEN SHILLINGS AND SIXPENCE

THE JOURNAL OF The Institution of Electrical Engineers

ORIGINALLY

The Society of Telegraph Engineers

FOUNDED 1871

INCORPORATED BY ROYAL CHARTER 1921

EDITED BY P. F. ROWELL, SECRETARY

SAVOY PLACE, VICTORIA EMBANKMENT, LONDON, W.C.2

Telegrams: "VOLTAMPERE, PHONE, LONDON." Telephone: TEMPLE BAR 7676.

Vol. 84 JANUARY, 1939 No. 505

CONTENTS.

The Institution is not, as a body, responsible for the opinions expressed by individual authors or speakers.

E. and F. N. SPON LIMITED, 57 HAYMARKET, LONDON, S.W.1.
CHEMICAL PUBLISHING COMPANY OF N.Y. INC., 148 LAFAYETTE STREET, NEW YORK.

The Institution of Electrical Engineers.

FOUNDED 1871

INCORPORATED BY ROYAL CHARTER 1921

PATRON: HIS MAJESTY KING GEORGE VI.

COUNCIL, 1938–1939.

President.

A. P. M. FLEMING, C.B.E., D.Eng., M.Sc.

Past-Presidents.

COLONEL R. E. CROMPTON, C.B., F.R.S.
SIR JAMES SWINBURNE, BART., F.R.S.
CHARLES P. SPARKS, C.B.E.
ROGER T. SMITH.
LL. B. ATKINSON.
J. S. HIGHFIELD.
F. GILL, O.B.E.
A. RUSSELL, M.A., D.Sc., LL.D., F.R.S.
W. B. WOODHOUSE.
W. H. ECCLES, D.Sc., F.R.S.
SIR ARCHIBALD PAGE.
LIEUT.-COL. K. EDGCUMBE, T.D.
COLONEL SIR THOMAS F. PURVES, O.B.E.
CLIFFORD C. PATERSON, O.B.E., D.Sc.
J. M. DONALDSON, M.C.
PROF. E. W. MARCHANT, D.Sc.
P. V. HUNTER, C.B.E.
PROF. W. M. THORNTON, O.B.E., D.Sc., D.Eng.
J. M. KENNEDY, O.B.E.
H. T. YOUNG.
SIR GEORGE LEE, O.B.E., M.C.

Vice-Presidents.

SIR NOEL ASHBRIDGE, B.Sc. (Eng.).
J. R. BEARD, M.Sc.
PROF. C. L. FORTESCUE, O.B.E., M.A.
JOHNSTONE WRIGHT.

Honorary Treasurer.

W. MCCLELLAND, C.B., O.B.E.

Ordinary Members of Council.

T. E. ALLIBONE, D.Sc., Ph.D.
COL. A. S. ANGWIN, D.S.O., M.C.
L. G. BRAZIER, Ph.D., B.Sc.
T. CARTER.
P. DUNSHEATH, O.B.E., M.A., D.Sc.
C. E. FAIRBURN, M.A.
F. FORREST.
PROF. R. O. KAPP, B.Sc.
E. M. LEE, B.Sc.
E. LEETE.
S. W. MELSOM.

Ordinary Members of Council—(*Continued*).

P. L. RIVIÈRE.
P. J. ROBINSON, M.Eng.
C. RODGERS, O.B.E., B.Sc., B.Eng.
C. D. TAITE.
C. R. WESTLAKE.
G. A. WHIPPLE, M.A.
A. P. YOUNG, O.B.E.

Chairmen and Past-Chairmen of Local Centres.

Argentine Centre:
C. G. BARKER.
*H. C. SIDDELEY.

China Centre:
S. FLEMONS.
*C. S. TAYLOR.

Irish Centre:
J. W. O'NEILL.
*LT.-COL. K. E. EDGEWORTH, D.S.O., M.C.

Mersey and North Wales (Liverpool) Centre:
E. L. MORLAND.
*G. K. PATON.

North-Eastern Centre:
F. A. ORCHARD.
*W. D. HORSLEY.

North Midland Centre:
J. W. ATKINSON, I.S.O.
*J. G. CRAVEN.

North-Western Centre:
W. FENNELL.
*J. W. THOMAS, LL.B., B.Sc.Tech.

Scottish Centre:
W. J. COOPER.
*MAJOR H. BELL, O.B.E., T.D.

South Midland Centre:
H. FAULKNER, B.Sc.
*H. HOOPER.

Western Centre:
H. S. ELLIS.
*H. G. WEAVER.

* Past-Chairman.

Chairmen of Sections.

CAPTAIN B. S. COHEN, O.B.E. (*Meter and Instrument*).
S. R. SIVIOUR (*Transmission*).
A. J. GILL, B.Sc.(Eng.) (*Wireless*).

Secretary.

P. F. ROWELL.

Assistant Secretaries.

F. W. HEWITT, M.Sc.; A. E. RAYNER.

LOCAL CENTRES AND SUB-CENTRES.

ARGENTINE CENTRE.

Chairman.—C. G. BARKER.
Hon. Secretary.—R. G. PARROTT, Tucuman 117, Buenos Aires.

CHINA CENTRE.

Chairman.—S. FLEMONS.
Hon. Secretary.—W. MILES, c/o Shanghai Telephone Co., P.O. Box 1193, Shanghai, via Siberia.

IRISH CENTRE.

Chairman.—J. W. O'NEILL.
Hon. Secretary.—R. N. EATON, 1, Foster Place, College Green, Dublin.

MERSEY AND NORTH WALES (LIVERPOOL) CENTRE.

Chairman.—E. L. MORLAND.
Hon. Secretary.—W. PARRY, M.Eng., "Scaur," Birkenhead Road, Gt. Meols, Hoylake, Wirral, Cheshire.

NORTH-EASTERN CENTRE.

Chairman.—F. A. ORCHARD.
Hon. Secretary.—L. MELLOR, "Burn Brae," Heworth, Gateshead, Co. Durham.

Tees-Side Sub-Centre.

Chairman.—H. H. MULLENS.
Hon. Secretary.—H. SHAW, "Glenholme," Boosbeck, Saltburn, Yorks.

NORTH MIDLAND CENTRE.

Chairman.—J. W. ATKINSON, I.S.O.
Hon. Secretary.—K. C. COOP, B.Eng., 36, Park Place, Leeds, 1.

Sheffield Sub-Centre.

Chairman.—H. W. KEFFORD.
Hon. Secretary.—A. C. BOSTEL, 23, Stumperlowe Mansions, Fulwood, Sheffield 10.

[*Continued on page (III) of Cover.*

A. P. M. Fleming

PRESIDENT 1938-1939

Lafayette, Photo. Emery Walker Ltd., ph. sc.

THE JOURNAL OF
The Institution of Electrical Engineers
VOL. 84.

INAUGURAL ADDRESS

By A. P. M. FLEMING, C.B.E., D.Eng., M.Sc., President.*

(*Address delivered before* THE INSTITUTION, *20th October*, 1938.)

The international crisis through which we have recently passed has focused attention on the importance of personal national service, and has brought into relief the vast extent of the technical knowledge and experience possessed by the members of The Institution, which could, in an emergency, be called upon to supplement the normal defence services. Should the occasion unhappily arise for this experience to be requisitioned for this purpose, it will, if used with wisdom and discrimination, be a national asset of incalculable value.

Each year the membership of The Institution increases and its activities expand, and thus it reflects the growth of the great industry with which we are identified.

My connection with The Institution since I joined as a Student extends over 40 years—a period during which changes in the industrial and economic life of the community have occurred with a rapidity and magnitude exceeding all previous periods of economic evolution. This period has witnessed the most active developments in electrical engineering; for, during it, the use of electricity has passed from being an expensive novelty to an almost all-pervading influence.

This growth in the use of electricity has been influenced by many factors, but it is due fundamentally to the fact that the material progress of civilization depends on power and that the amenities needed to satisfy the innate desire of man for an improved standard of living are obtainable only through its use. At present, electricity is the form of power that is most economical and convenient in application, and it is almost the only form that is available for the personal employment of the individual.

That the demand for electricity is far from being satisfied is evident. The factories and dwelling houses not at present electrified or only partially so, the extension of power supply to rural districts, the electrification of railways, the demands for higher standards of living, the desire for the elimination of arduous labour, and the need for efficient production of marketable commodities, offer many possibilities for the further use of electricity. Moreover, the continuous expansion of scientific knowledge progressively stimulates the development of new industries and industrial processes which require the application of power.

This demand for electricity has resulted in the exploration of every natural primary power resource and its conversion into electrical form, with its subsequent transmission and distribution to the user. Contemporarily it has called for the invention and the scientific development and manufacture of the plant required for these purposes, and of the ever-increasing range of electrical power-absorbing devices.

The two main aspects of electrical engineering—the supply of power and the manufacture of plant and equipment—are mutually interdependent, and their development should proceed with the closest co-operation.

Lack of initiative and efficiency in either branch, or in any element of either branch, affects the whole industry adversely, and healthy and progressive development depends on the wise and farsighted conduct of the industry as a whole.

The engineer is primarily concerned with those activities resulting in the conversion of natural resources into usable form; for example, the energy of coal or falling water is converted into electrical energy; iron ore, limestone, coal, and other raw materials, are converted into turbines and generators. The feature of fundamental importance in this conversion is that it shall be accomplished with the utmost efficiency, that is, with the minimum waste of time, effort, and materials.

Two basic factors determine at any particular time the standard of efficiency that is attained: one is the quality of personnel available for each operation, however important or however insignificant; the other is the facilities available for extending the boundaries of scientific knowledge and for ensuring its fullest application.

* Metropolitan-Vickers Electrical Company, Ltd.

THE CHANGES IN INDUSTRY THAT AFFECT THE PROBLEMS OF PERSONNEL AND RESEARCH

On the power-supply side of the industry, farsighted and progressive supply engineers of great courage and ability have advanced the application of natural physical laws progressively to the limits of practical achievement at any particular time, and as a result the status of power supply in this country bears very favourable comparison with that elsewhere.

The introduction of the steam turbine towards the end of last century has exercised a profound influence on the development and efficiency of electrical power supply. The great increase in speed which this introduction brought about has resulted in the ability to develop enormous power in single units and has revolutionized the design of electric generators.

The use of increasingly high steam pressures and temperatures, and other developments connected with prime movers, have been based on a scientific consideration of the maximum economic benefits obtainable with all possible factors taken into account. The co-operation between the leaders in power-supply undertakings and the engineers engaged on the manufacturing side has been commendable and of the utmost benefit to the industry as a whole.

Much attention has been directed to the use of the mercury boiler and other binary fluid cycles, and the developments in this direction which are in progress in the United States will continue to be observed with much interest.

The economic possibilities of generating at 33 000 volts, and even higher voltages, have been taken advantage of, and the gains to be achieved by hydrogen-cooling for large electrical plant have not been overlooked.

With the growth of power systems, correspondingly marked changes have taken place in the development of transformer units and in the design of circuit-breakers capable of interrupting effectively the enormous powers that have to be controlled. Not less progressive have been the developments in high-voltage cables and in the many forms of ancillary apparatus necessary in modern transmission and distribution practice.

Each development has involved the solution of new technical problems, the difficulty of which has been exaggerated by the vital need to ensure continuity and safety of supply under conditions of increasingly complex interconnection between large power-supply systems. This has called for continuous improvements in protective apparatus against lightning and other disturbances, and intensive study of the distribution and control of transient potentials in the windings of high-voltage apparatus.

Since the beginning of this century electrical manufacture in this country has emerged from a weak and struggling condition into a healthy and powerful state. In earlier years small, keenly-competitive companies were unable either to develop the strength required to expand into overseas markets or to compete successfully with strong international manufacturers even for the markets in this country.

The leaders of the industry showed great perception when in 1911 they founded the British Electrical and Allied Manufacturers' Association, in the belief that voluntary co-operation between the various firms would go far to overcome the economic difficulties which at that time were handicapping the development of electrical and allied manufacture in Great Britain.

Taking "co-operation without sacrifice of individual initiative" as its economic principle, the Association has progressed until it can now claim that its members manufacture practically the whole of the electrical machinery and apparatus produced in this country. Its many activities, including the standardization of designs and the fostering of research, have done much towards raising Britain to a leading place among exporters of electrical equipment. Through its agency the energy heretofore expended in unrestricted competition has become largely directed towards building up the combined strength of the industry, and in providing the means for that healthy development and progressive improvement in production and products which was impossible under the previously existing conditions. Such measures afford the only durable protection of an industry which is so international in character.

Few manufacturing industries have progressed technically at such an enormous rate as has electrical engineering, and one of the results of this has been to increase the rate of obsolescence of plant long before its normal life and durability have been exhausted.

Scientific and technical research has revealed new electrical applications such as those concerned with communication, illumination, broadcasting, the cinema, domestic uses, and the hospital, and each of these has added new and rapidly growing industries. Forty years ago practically the whole of the invested capital, employment, and manufacturing activity of the industry, was concentrated on heavy electrical plant and apparatus, whereas at the present time the light-current side, embracing the above and other fields of electrical application, actually exceeds, at any rate in production, the value of the heavy-current side. A result of this change has been a very great extension in the industry of the use of mass-production methods.

Modern manufacturing organizations have in many instances grown to great size, requiring a range of personnel quite different from that of earlier years and affording scope for every type of ability and aptitude. An important feature has been the increasing ratio of staff to manual workers. One reason for this is the intense need for efficiency in manufacturing operations, which has called for a considerable increase in the number of high-grade staff on the lines of communication between the management and the productive workers.

Since the beginning of the century the technically-trained engineer has found scope first in connection with design, then in selling, and more recently in production work. The appreciation of the need for research opened up the field for scientifically-trained engineers, physicists, metallurgists, and chemists, and the modern production organizations are affording increasing scope for the engineer administrator.

As pointed out by Mr. H. T. Young in his Presidential Address two years ago,* contracting work, that important

* *Journal I.E.E.*, 1936, vol. 80, p. 1.

link between electricity-supply authorities and the consumer, is also offering possibilities for an improved standard of personnel.

The changes affecting the skilled manual worker have been equally marked. The growth in application of mass-production methods has diminished the demand for certain types of handicraft skill, but, on the other hand, has greatly increased the demand for workers skilled in making the tools of production. In other phases of manufacture, such as that of heavy power plant where production is not susceptible to mass methods, the constant change in materials and processes calls for the same degree of adaptability on the part of the worker as was required of the craftsman of earlier days.

Reverting now to the consideration of the two basic factors already referred to, namely personnel and research, and dealing first with the subject of personnel, my observations are directed more particularly to the manufacturing branch of the industry, which employs nearly 70 per cent of all the workers engaged in the industry as a whole.

PERSONNEL

The personnel problem is primarily that of selecting, educating, training, and effectively using workers best suited to the various grades of employment, and its importance is such as to justify the use of every resource that will advance these objectives, since the prosperity and progress of any industry depend essentially on the adequacy and efficiency of its personnel.

There are three principal educational levels of entry into the electrical industry. In the lowest of these are those youths who are recruited at the ages of 14 to 16 years from the elementary, central, junior technical, and junior secondary schools; the intermediate level comprises those from 16 to 18 years of age who have reached Matriculation or Higher School Certificate standard in secondary schools, while in the highest level are those who enter as graduates from the universities and large technical colleges.

The electrical profession is a democratic one, in that no matter at what educational level a youth enters he can, given the ability and ambition, climb to the highest ranks.

The importance of attracting the very best recruits from each level and of encouraging, and affording facilities for, the upward mobility of the individual according to his aptitude and capability cannot be overestimated. We are fortunate that in this country these conditions are widely recognized and provided for, in striking contrast to the method of certain other industrial countries.

At whatever educational level the recruit enters the industry, the first consideration is that of selection. This is a matter of equating the aptitude of the entrant to the requirements of the job. Much has been done by the psychologist in attempting to solve this equation by scientific methods, and much remains to be done in this direction. I am of the opinion that for most types of industrial employment, especially those concerned with the skilled trades, the best results are obtained when methods of self-selection are employed and the entrant is given an opportunity, after he has had some manufacturing experience under sympathetic guidance, of deciding for himself the trade or branch of work to which he is best suited.

Considering first the entrants to the industry from the lowest educational level, on the manufacturing side these are destined to become manual or junior clerical workers, although many take such good advantage of the part-time educational facilities available that they obtain subsequent promotion to technical and administrative positions. Economic and social changes have had a marked effect on the number and type of applicants for training for this manual employment, for many youths who, in earlier times, would have found their future in the workshops now seek, and have many opportunities for obtaining, non-manual employment of a character possessing no productive or creative value, and offering, in most cases, very little prospect of a progressive career.

Manufacturing conditions call to-day for adaptability on the part of the worker; and to an increasing extent the skilled artisan requires, in addition to the acquisition of manual dexterity, a measure of trade instruction which will keep him progressively acquainted with, and make him readily adaptable to, changes in processes and methods of production. Most technical schools offer workshop courses which aim to provide such instruction, while alternatively many large engineering manufacturers seek to accomplish it even more effectively through their own works' schools.

Within the last quarter of a century the growth of junior technical schools has been one of the significant developments in industrial education. These schools provide courses having an industrial bias for those youths from the primary schools who are not able to proceed to secondary schools. From considerable experience of students from these schools, I am convinced of their great value to industry. Such schools do not, however, as far as I have been concerned, contribute very prominently to the supply of craftsmen, since the great majority of their students experience little difficulty, on the completion of their apprenticeship training, in obtaining junior staff positions. They do assist materially, however, in filling that important need for an adequate supply of non-commissioned officers of the foreman and the works' superintendent type.

An increasing number of youths entering from this lowest educational level secure promotion through following a course of technical study leading to the Ordinary and Higher National Certificates. In this connection The Institution has performed a great service to the industry through the medium of its close co-operation with the Board of Education on the award and recognition of these certificates, through preparation for which large numbers of men who entered the industry at an early age have acquired the technical knowledge necessary for their elevation to positions of responsibility. In most cases this preparation requires attendance at evening classes over a period of several years, but there is now an increasing, and very gratifying, tendency on the part of employers to permit their apprentices to attend equivalent part-time day courses at the local technical institutions.

This democratic tendency to encourage these young

men to climb upwards is in sharp contrast to the system in operation in Germany where, for the most part, the upper level attainable even by an ambitious youth is dictated by his starting level—a restricting feature which must react considerably on the enthusiasm of one thus forced to resign himself to a predetermined status with little, if any, prospect of further advancement. This condition may be compared on the other hand with the U.S.S.R. plan which, with certain political limitations, endeavours to select, educate, and train its entrants to industry solely on the basis of merit—a plan wholly admirable in theory and to a considerable extent operating satisfactorily in practice.

With regard to the intermediate and higher educational levels, it has long been the custom to introduce into industry young men from the secondary and public schools, technical colleges, and universities, who, after suitable training, proceed to staff employment. For those who enter at, say, the Higher School Certificate level, the large electrical manufacturing organizations provide a course of practical training extending over a period of about 4 years, during which time the trainees acquire by part-time study the technical knowledge requisite for their future staff employment. Those who pursue a university course in an applied science faculty and obtain a satisfactory degree, are admitted to a shorter course of practical training of the order of 2–3 years. An alternative course which I have found to offer many advantages comprises one year of practical training in works prior to, and one following, the university course. This provides an opportunity for the youth of 16 to 18 years, who up to this time has had no experience to guide him and who may have shown no special aptitude for any particular vocation, to learn at first hand what engineering is like without prejudice to his future career, even should he decide afterwards on some other profession.

It is generally accepted in this country that an engineer should pass through a course of practical training, whereas in some industrial countries this phase of experience is omitted in the case of a technically-trained entrant to the industry. The character of the practical training is important. One of its purposes is to give the young engineer a thorough acquaintance with the construction and function of the engineering apparatus of his firm; an understanding of the fundamental industrial processes involved and of the limits of refinement appropriate to the efficient working of the plant manufactured; a knowledge of the organization of an industrial concern; and an appreciation of the need for continual vigilance in the matter of application of new scientific and technical knowledge within the industry. The second function is to afford a bird's-eye view and some experience of the main divisions of the manufacturing industry, viz. design, production, selling, and research. During the period of his training he will become sufficiently acquainted with these branches to be able to determine for himself to which of them he is most attracted, and to solve for himself the equation of his aptitude and ability to the requirements for success in a chosen branch.

As regards the technical side of his training, the education now available in the universities and technical institutions requires careful consideration in the light of modern requirements. In the past, industry looked to the universities to supply students who were fully equipped technically. The position to-day is that with the immense amount of research that is done within individual organizations, and the rapidity of development of new engineering plant and apparatus, the leadership in technical advance lies with industry, and it has now become increasingly important to consider the student from the university as one whose general education has been supplemented by a sound study of the principles in pure and applied science, which is to constitute the basis for the acquisition of more specialized technical knowledge when he finds his bent and field of work in the industry.

This condition has been recognized in Manchester by the recent establishment of Post-Advanced Regional Courses of Technical Instruction in electrical and mechanical engineering. The courses are given by experts drawn for the most part from industry, and are intended for students who, having completed a university Degree or Higher National Certificate course, are engaged in work to which the specialized knowledge dealt with is particularly applicable. They include information relating to new materials and processes, methods of design and measurement, and the regulations affecting electrical undertakings. After each lecture a period is allowed for discussion, at which students may contribute their own experiences on the subject under consideration.

From another viewpoint the educational needs of the industry are admirably served by the technical Press, which provides up-to-date knowledge on subjects ranging from the most recent scientific and technical discoveries to the latest developments in power supply, manufacture, and electrical applications. It is of service to the entire personnel of the profession and is an important factor in the progressive advancement of the industry as a whole.

Technical graduates in a large organization will, on the completion of their apprenticeship, for the most part have determined the branch of the industry to which they feel most attracted, and will have secured a footing in their chosen field. The opportunities for the graduate in design, technical sales, and, more latterly, in the production side of industry, are well established.

In the case of those graduates who proceed to the productive and administrative sides, courses in industrial administration are now available in various centres. Administrative work affords a very promising field for the young engineer who has developed the requisite capacity for this side of the profession.

It will be noted that, throughout this consideration of personnel, I have urged that a young engineer should determine for himself, by preliminary experience, the line of work to which he feels most attracted and in connection with which he can satisfy himself that he possesses the ability to carve out a successful career. This, however, is only the starting point; in my experience the young engineer who has been satisfactorily trained technically, given an opportunity for the exercise of initiative, often develops his inherent personal qualities in such a way that they may eventually outweigh the value of his technical knowledge.

The rapid development of research in industry in recent years has brought about the need for special and appropriate staff, and the most suitable training for such staff is still a matter for determination. Some industrial organizations prefer to draw from the university those students who have followed a post-graduate course in research. Others prefer to train their own research workers.

Under the conditions of research with which I have been most concerned, I have found it of advantage to select university students and give them a preliminary practical training in the works before entry to the research laboratories. This broadens the experience of the apprentice and gives him an opportunity of determining whether he really is well adapted to research work, otherwise he may make a faulty decision before he has had any opportunity of basing his judgment on actual experience. During his training in the research laboratories he will be given specific courses of lectures by specialists, which will advance his scientific knowledge and his mathematical capacity and will broaden his interest in the economic aspects of research and in the practical applications of research results. If he continues in this work and eventually shows a capacity in a special field of research, consideration is given to his return to a university or research organization somewhere in the scientific world where he can pursue an advanced course of study in this field.

While in the past a good deal of attention has been paid to the training of the rank and file, and of the technical graduate, by a few progressive concerns who have largely carried the burden for the whole industry, too little attention has been paid, even by these, to the training of staff for the higher executive positions. This has become more and more a matter of grave concern, for the maintenance of our position in international competition depends essentially on good leadership. It behoves every concern to look ahead and be prepared to earmark its progressive staff officers at a relatively early age and give them the requisite breadth of experience, even at the risk of having to carry some supernumerary staff, in order to provide a force from which the highest executive positions can be filled. At present the tendency in so many organizations is to deal with this problem in a very haphazard way. In this connection recreational activities often reveal and develop latent organizing ability and capacity for leadership which might pass unnoticed in the ordinary working life of the young engineer.

The strong position of the electrical industry, both at home and in international markets, is in no small measure due to the advance during this century of the technical level and excellence of training of its personnel. In this connection the training for export trade is of great significance. Overseas trade is important not merely to the manufacturer but to the entire industry, since the technical requirements for much of the plant and equipment sent overseas provide valuable knowledge and experience which may ultimately be of great use in the home market. For example, until the development of the grid, the home market provided little experience in the design and manufacture of high-voltage plant, whereas the conditions in the export market had long demanded such developments, and the firms who had undertaken such work were in an excellent position to employ their knowledge and experience at home when the occasion arose.

The opportunities afforded by the leading manufacturing concerns to young engineers from the overseas parts of the Empire and from foreign user countries represent a farsighted policy. In the company with which I am associated this practice has been followed over a period of more than 30 years, and during that time nearly 1 000 young engineers from overseas have been fully trained in British electrical practice. The establishment of the British Council and its activities in encouraging young people to come to this country for education and training marks an important step in the furthering of British industrial and commercial interests overseas.

RESEARCH

Now to consider the other basic factor to which I have referred, namely research. The responsibility of the electrical engineer of transforming natural sources of power into electrical form, and of converting raw materials into finished electrical products, calls for continual research to determine and apply every possible means of achieving these ends in the most efficient and economic manner possible. The field for research is thus very broad. It embraces every physical science, and ramifies into applications of materials, processes, and technical methods. It involves a continual appreciation of the significance of new scientific discovery and invention in relation to methods of measurement and of manufacture, and concerns itself also with a study of the efficient use of human effort.

The function of industrial research is to bridge the gap between the birth of an abstract idea and its ultimate commercial application. The intervening links are those relating to the scientific testing of the idea, the research required to see whether it has application to any particular industrial objective, the semi-scale experiments to evaluate its economic possibilities, the provision of capital for its exploitation, the training of staff, and the provision of equipment to turn the idea thus developed into concrete practical use.

In bygone days, ideas were conceived and developed by the individual effort of men of genius; to-day, in the universities and great scientific laboratories teams of scientists are at work extending the boundaries of knowledge out of which possible applications in industry may emerge. Within the past two decades there has been great activity in industry in the study of the ways and means whereby such fundamental discoveries in science can be turned to account, and in the great manufacturing organizations increasingly large and better technically-trained staff is being employed to effect the practical application of the knowledge that this industrial research yields.

Many of the new discoveries affecting our industry arise from the work of the physicist. The field in which the physicist now works has developed in such a manner that compared with a decade or so ago he often needs for his researches plant of great engineering magnitude—plant which may yield many hundreds of thousands of

kilowatts or many millions of volts. On this account, as well as for other reasons, it is probable that the great manufacturing organizations will undertake more and more fundamental research, as well as increase their research activities of a more specifically applied character.

A pleasing feature in the last decade has been the tendency towards co-operative research whereby problems of common interest to a large number of different organizations in the same industry are pooled. This avoids overlapping of effort and has enabled the smaller concerns to profit equally with the large ones, for the knowledge thus revealed is available to all on the same common basis as a raw-material supply.

A great deal of the responsibility for continued technical development falls on the manufacturer. On the other hand, no small responsibility rests on those concerned directly with the disposal, utilization, and servicing of his products, for acquainting him fully with the special needs to be satisfied and for advising him as to the most likely means of removing outstanding deficiencies in the operation of these products.

Especially is the manufacturer concerned with improvement in the materials of construction which constitute such a large proportion of his manufacturing costs. To the engineer falls the task of devising appropriate methods of test, of studying the properties governing the suitability of different materials for particular engineering applications, and for ensuring their most effective and reliable utilization.

The selection of materials must always be based on the results of accumulated experience and of comparative testing under conditions approximating to those likely to be experienced in practice. Given a number of materials, the engineer can be relied upon to devise means of deciding upon their relative suitability for specific purposes, but the time has arrived when he would like to visualize the possibility of " designing " materials for these purposes on a scientific basis without recourse to the " hit-or-miss " procedure on which he has had to rely so much in the past. We are only at the beginning of an understanding of the solid state. The problems involved are of extreme difficulty; but it is because they are difficult that they demand the closest possible co-operation between workers in all the branches of science involved. If the chemist and the physicist are to operate, from the engineer's point of view, to best advantage they need to become acquainted in as full a manner as possible with the requirements which the engineer would like them to satisfy. It is gratifying to observe a growing intercourse between groups of chemists and physicists and engineers—an important aspect of this is the increasing recruitment of physicists, in particular, to the staffs of electrical engineering firms.

Let us consider a few examples indicating the direction which the study of materials of engineering construction is taking. For instance, in connection with metals, the magnitudes of the inter-atomic force of cohesion in the crystal structure have been the subject of analytical estimation, which indicates that the theoretical strengths that are possible may be vastly greater than those actually obtained at rupture. These theoretical strengths are not obtainable, because slipping occurs under shear stress at certain crystallographic planes. It is this slipping which accounts for ductility, and since some measure of ductility is generally desirable in constructional work, materials possessing cohesive strengths approaching theoretical values would not necessarily be regarded as ideal. The margin for improvement is, nevertheless, very wide. Advance in the rupture strength has been obtained by stiffening up the crystal lattice against slip by alloying and by cold working which produces distortion of the space lattice. The rather haphazard investigations that have led to advances in this direction are giving way to a more systematic attack on the problem, and no doubt considerable advances will be made with more complete knowledge.

The researches on alloy steels, which have resulted in materials possessing tensile strengths at atmospheric temperatures, combined with appreciable ductility, up to 80–100 tons per sq. in., have been extended during recent years to the study of steels for use at elevated temperatures. As the result of this research, constructional steels are now available which will carry safely at 1 000° F. four to five times the stress possible less than 20 years ago. In consequence, the last few years have witnessed very considerable progress in the design of steam power-plant for operation at increasingly high pressures and temperatures. It is not unlikely that the next 20 years will see the development of high alloy steels of high strength and durability capable of operating at red-heat temperatures—well above those now practicable in power plant.

New methods of studying the properties of materials are continually being devised. For example, the application of X-rays and electron diffraction methods of measurement are proving of great engineering value. X-ray crystallographic analysis enables the phase pattern of a metal to be determined, and in certain cases also the distribution of the different atoms on the available sites in this pattern. Such analysis also yields information as to the size and orientation of the grains —information of great value in studying the directional properties of the worked materials. At the same time, X-rays are proving a valuable engineering tool for the detection of cracks and flaws and provide a non-destructive test of particular value in highly stressed components, while electron diffraction methods are finding increasing application in the study of such engineering problems as lubrication and corrosion. The knowledge thus revealed by metallurgical research is likely to reduce very considerably the amount of experiment in the search for new metals of improved properties.

Developments in magnetic materials are likely to contribute considerably to improvements in the weight efficiency of electrical plant. During the present century many improvements have been made in the quality of magnetic materials, particularly in sheet form. The reduction of certain impurities to an extremely low value, the care in rolling and annealing processes, special thermal treatments in various atmospheres, the cold working and attention to the whole range of alloying materials, represent lines of research along which advances are being made. Here again researches are assisted enormously by modern technique in the study of crystallography, since the magnetic

properties of commercial materials are the sum total of those of the individual grains or crystals in polycrystalline material, and the character and alignment of the crystals are all-important. The fact that the present commercial sheet magnetic materials give a maximum permeability of about 6 000, compared with the permeability of 1 430 000 obtained in the laboratory by the careful treatment of single crystals and by selecting certain crystal directions, gives some indication of the field still to be explored.

Among the outstanding advances in magnetic materials has been the development of the nickel-iron group of alloys, which afford an excellent example of the value of systematic research work. Materials of this class possessing initial permeabilities of the order of 20 000, and a maximum permeability of over 100 000, are now in common use for electrical communication purposes.

No less remarkable has been the rapid recent development of the ternary and quaternary alloys for permanent magnets. In 1915 the best permanent-magnet material was tungsten steel, with a coercivity of 80, whereas the present commercial nickel-aluminium-cobalt alloys have a value seven times as great. It is probable that the limit in this field has not yet been reached, since other alloys—at present too expensive for commercial exploitation—have been discovered with coercivities six or seven times greater still.

No subject is of wider interest and importance in the electrical industry than that of insulation, and yet, as stated by Prof. Thornton in his Presidential Address a few years ago,* "in no other engineering field does the designer receive so little instruction and guidance from the application of established general principles and basic theory." Unfortunately, this remains largely true, although, owing in the first place to the increasing number of research workers in this field and to the growing activity of the chemist in producing new synthetic materials, the outlook of the electrical designer in this respect becomes steadily brighter.

The development of plastic materials, both for insulating as well as for a variety of decorative and other purposes, has been one of the outstanding industrial features of this century. To an increasing extent materials of this kind, of a wide variety of chemical composition, are finding applications in electrical apparatus.

There is a particular need at the present time for dielectrics suitable for use in connection with the insulation of very short-wave radio apparatus. Much study is being given to this problem, and some notable advancement has been made in ceramic materials, but, unfortunately, mainly in other countries.

In other directions the last few years have seen come into prominence acetylated cotton fabrics of improved moisture-resisting properties, various chlorinated hydrocarbons as replacements for transformer oil and as fire-resistant wire coverings, polymers of non-polar substances of low dielectric loss for radio and telephone applications, artificial rubber with vastly improved oil resistance, and insulating varnishes of the glyptal type, alongside a steady improvement in the quality and uniformity of well-known and long-established "natural" products.

* *Journal I.E.E.*, 1935, vol. 76, p. 1.

Incomplete as is our knowledge of the mechanisms underlying the electrical behaviour of these materials, the greater need is perhaps for a better understanding of the relation between the physical properties and chemical composition. These properties are inherently more difficult to study scientifically than the purely electrical ones, and as yet the development of appropriate scientific techniques of measurement is in its infancy.

The significance of improvement in the physical properties of the materials employed in construction, particularly in such plant as generators, transformers, and motors, is not always realized. The improvement in weight efficiency is cumulative, so that the ultimate gain in manufacturing cost may be out of all proportion to the cost involved in securing the original improvement in the material. A notable example was the effect of the introduction in 1907 of silicon steel for transformer work, which resulted in the reduction of weight and in the increase in efficiency of transformer cores, with a corresponding reduction in the weight of transformer windings, in the quantity of oil for cooling, in the size of containing cases, and in the space occupied by the finished product.

The discovery of oils and greases having very low vapour pressure has, during the last decade, transferred vacuum technique from a laboratory to an engineering scale, and has permitted the development and use of continuously-evacuated equipment which can be made almost completely in metal, with corresponding robustness of design, ease of dismantling, and replacement of working parts.

Another direction in which research in the last few years has been of great engineering value is the study of acoustical measurements whereby sources of noise in plant and equipment can be traced, and guidance given to engineers for their elimination.

It is gratifying to the electrical engineer that in every direction where minute displacements, refinements of measurement of dimensions, the recording of the smallest elements of time—in fact, refinement of measurement of every physical character—are concerned, electrical means are increasingly employed. It is through the science of measurement so greatly facilitated by electrical means that exact knowledge is obtained and the boundaries of science extended.

I have cited only a fraction of the interesting and important fields of research that are being explored by the great research organizations associated with manufacturing companies in different parts of the world, in the laboratories of certain of the universities and those of a national character, to say nothing of the very wide range of research work of electrical interest carried out under the control of the Electrical Research Association, with which our Institution is so closely identified.

This progress towards a better understanding of the behaviour of materials and towards a more scientific basis for their development and production will show itself in continued improvement in the design of plants, and consequently in the efficiency and reliability of power generation and transmission, without, so it would appear, any fundamental change in the principle underlying these vital processes.

In the near future, the fundamental changes in

technique to be expected as the boundaries of scientific knowledge extend lie rather in the sphere of power utilization. The discovery of the thermionic valve, for example, and the knowledge which the widespread study of electronics and vacuum physics has provided, have opened up a field for electrical development which has already progressed far, but from which many more developments can reasonably be expected.

Contemporary with such activities there is proceeding in all parts of the world the unremitting search by eminent workers for new scientific knowledge, out of which may come information that will form the starting-point for new industrial research. Out of this wide field of investigation certain lines of study are at once suggestive of possibilities bearing on our industry, as, for example, the knowledge that may arise from investigations relating to mono-molecular layers, to nuclear disintegrations, and to the behaviour of materials at very low temperatures.

Owing to the continual accumulation and application of new scientific knowledge, the electrical industry is ever changing. Researches into electrical phenomena have contributed largely to the growth of this knowledge, the application of which has exercised a profound influence on our communal life. It has placed at the disposal of mankind, goods and services which men are not yet able to utilize nor control to full advantage, and it has produced, or at least exaggerated, many social problems. These are receiving increasing attention not only in this but in other countries, and the study of the social relations of science is a growing concern of many scientific bodies.

These and the more immediate problems of our profession are the concern of our Institution. It is the responsibility of our generation to pass on with undiminished prestige the heritage handed down to us from those who in earlier years laboured to found our Institution and to foster its growth. Not the least important phase of this responsibility is that concerned with the education and training of those who will be its future members and on whom will ultimately fall the onus of leadership.

In adapting ourselves to meet rapidly changing conditions, we may well take note of the ruthless efficiency and the direct and speedy action of the totalitarian states in matters concerning social, economic, and industrial affairs. It is possible that such efficiency, attained at the expense of individual initiative, may be purchased at a very high price, but the challenge thus thrown down can only be met in a country like ours by such effective voluntary co-ordination as will secure the major benefits of a united front, with the added advantage of the preservation, in a large measure, of freedom of initiative and individual enterprise which, as a nation, we prize and which has served us well in the past.

Already in our industry we have had experience of the benefits of such voluntary co-ordination as in the British Electrical and Allied Manufacturers' Association and the Electrical Research Association, to quote only two examples, and much might be accomplished by a more complete consciousness of this principle. In this connection, the problem of education and training justifies careful consideration.

To a considerable extent the manufacturing companies are best adapted to provide the preliminary practical training for recruits for other branches of the industry. In this matter of practical training of all grades of workers, however, there is a very large disparity between the facilities provided by the different manufacturing organizations, and the resources of the industry are by no means adequately used in equipping in the best possible manner the young personnel on which the industry will eventually depend. A few concerns have undertaken the problem seriously. Co-ordination between the large firms and groups of specialist firms which possess the facilities for suitable training should be possible. The result would be to raise the technical level of the industry, which would react in improved trade, particularly overseas trade, from which all would gain.

During the past quarter of a century the companies with which I am associated have trained many thousands of young engineers who have entered the industry from the various educational levels. A minority of these have remained in the employ of the companies; the remainder have been absorbed by the industry, some by competitive firms, some by supply organizations, some by operating engineering, and many others in teaching posts in universities and technical colleges throughout the world. The knowledge gained from this experience justifies the belief that much benefit would arise from a greater co-ordination of training facilities among manufacturers. Such co-ordination would materially assist in the planning and arrangement of university and technical courses best suited to the industry's need. It would also facilitate the establishment of "refresher" courses in works for the staffs of universities and technical institutions. Experience in operating a number of such "refresher" courses has convinced me of their very great usefulness, which, I am sure, is also realized by the teaching staffs.

To assist in interrelating each branch of the profession, it might be desirable to arrange for a selected number of young engineers to obtain some practical experience in all the important phases of the industry: manufacture, power supply, distribution, and contracting. The experience of such a group would be of considerable value in the industry's councils, and would assist in ensuring greater uniformity in the progressive development of each branch of the industry.

In a highly technical profession such as ours, we attach great weight to the acquisition of scientific knowledge and experience, and the young engineer must necessarily give the closest attention to this aspect of his education and training, but it should not obscure the development of those personal qualities that are really the factors which determine success in any career. It is important similarly to encourage the young engineer to avoid isolation from economic and social affairs, and to endeavour to foster the wise use of those forces and amenities which he labours to create.

In conclusion, I wish to say how deeply I appreciate the honour you have conferred upon me in electing me your President. I shall endeavour to carry out worthily the duties of that office.

TRANSMISSION SECTION: CHAIRMAN'S ADDRESS

By S. R. SIVIOUR, Member.*

(*Address delivered 9th November*, 1938.)

THE TRANSMISSION SECTION

The membership of this Section at the present time is 1 672, which is just over 9 % of the total membership of The Institution or 11 % of the members in the United Kingdom. Whilst that may be considered good progress for the 4 years the Section has been in existence, I cannot help feeling there are many whose interests would be well served by coming "within the fold" and whose presence and contributions at our meetings would enhance the work and prestige of the Section.

I need only remind you that the range of subjects within the province of this Section is very wide and, in addition to the advantage of specialized papers, lectures, and discussions, the visits to works or undertakings are valuable opportunities for making acquaintance with current practice. These visits, together with those to Continental undertakings, have been of great interest and, I venture to say, of some profit to those participating, and, moreover, have shown very clearly the unselfish way in which engineers, regardless of nationality, are ready to exchange and pool their knowledge and experience. I hope, therefore, that we shall all do our best to increase the membership of the Section.

The formation of Local Transmission Sections in the Local Centres would no doubt contribute to an increase in our membership. There are, however, difficulties in forming local Transmission and other Sections—and I speak with some knowledge of efforts made in one Local Centre—but I ask members, particularly those in the provinces, to keep the matter in mind as otherwise there is a danger lest these main Sections of The Institution may be looked upon as peculiar to London. I think we must also correct a prevalent impression that these main Sections are subsidiaries, whereas in fact they are, as the word implies, merely a section of the whole membership whose particular interests justify additional facilities for discussions and lectures with a status no less than that pertaining to Ordinary Meetings of The Institution.

I propose to address you on certain features of construction employed on the transmission and distribution systems with which I am associated, together with some data and remarks on service experience, and also to offer some general observations on a few kindred matters connected with the distribution side of the supply industry.

A brief outline of the history and extent of the undertakings of The Yorkshire Electric Power Co. and their associated companies may be of interest and enable you better to appreciate some of the matters to which I shall refer.

* Yorkshire Electric Power Company.

HISTORY OF THE YORKSHIRE ELECTRIC POWER COMPANY

Following the decision by Parliament that, where sufficient public advantage was shown, powers should be given to companies for the supply of electrical energy over large areas, including the districts of numerous local authorities, Special Acts were granted from 1900 onwards to power companies. Amongst these was the Yorkshire Electric Power Act of 1901, which was promoted by a number of Yorkshire manufacturers impressed with the importance of a general supply for power purposes.

The original area of supply covered 1 644 square miles, but you will remember that the Power Acts contained restrictions by which the majority of the most densely-populated districts were excluded from the distribution areas of the power companies, and the latter, while permitted to distribute electricity for power in the districts where there were no authorized undertakers, were prohibited from supplying for lighting only: in addition their tenure was only secure in respect of their bulk supply powers.

The population of the whole area is approximately 3 millions, of whom about 2 millions live in the restricted areas occupying only about one-quarter of the total area. The average density of population within the restricted areas is 7 persons per acre, as against 1 person per acre in the remaining area.

You will thus appreciate that the restriction referred to, together with other restrictions concerning the route of "through" mains in some of the cities and large towns, has made more difficult the task of supplying the remaining districts and has to no small extent influenced the layout of the transmission system.

To overcome the legislative restrictions it was necessary to establish a separate company for distribution and in 1905 Electrical Distribution of Yorkshire, Ltd., was formed for this purpose in co-operation with the Power Company.

Provisional and Special Orders to the number of 44 have been granted to the Distribution Co. since 1905, mostly within, but in some cases extending beyond, the boundary of the Power Company's area.

The encouragement given by the 1926 Act to the further development of domestic supplies in rural areas led to the grant to the associated companies, at various times, of further areas in the northern part of Lincolnshire, parts of Yorkshire, and small areas in Derbyshire and Nottinghamshire, which together bring the total area of supply in Yorkshire and adjoining counties to approximately 2 700 square miles.

A further scheme was promoted in Cumberland, where, in 1930, Electrical Distribution of Yorkshire, Ltd., were given powers to supply in an area of 863 square miles.

In the case of both the Lincolnshire and Cumberland areas, the provisions in the respective Orders in regard to tenure, standard prices, dividends, and development, made it necessary to form separate companies for administration purposes.

System Layout

With the exception of one or two very small supplies which under temporary arrangements are taken from neighbouring undertakers pending extensions of the Company's system, the whole of the supply in Yorkshire and adjacent areas forming the combined area of supply of the associated companies is given from one self-contained system, which includes three generating stations (Thornhill, Ferrybridge, and Barugh) and an extensive system of transmission mains operating at 66 kV and 33 kV with secondary distribution at 11 kV, the latter constituting the medium for direct supply to the majority of the bulk-supply and power consumers.

The higher-voltage transmission systems, operating at 66 kV and 33 kV, have been imposed on the original 11-kV distribution system, and with the establishment of main distribution substations the 11-kV network is sectionalized, thus providing for efficient voltage regulation, and affording—through ring or radial mains—interconnection between adjacent districts and minimizing interference under failure of supply in any section.

All 3 stations are "selected," and 2—Thornhill and Ferrybridge—are base-load stations for the Mid-East England area of the Central Electricity Board.

The following particulars relate to the combined systems in Yorkshire and adjacent counties, viz:—

Transmission and Distribution Mains.

	Underground	Overhead	
66-kV mains ..	—	118	118 miles
33-kV ,, ..	118	140	258 ,,
11-kV ,, ..	542	866	1 408 ,,
3/2-kV ,, ..	71	22	93 ,,
L.P. ,, ..	952	582	1 534 ,,
		Total	3 411 miles

Substations and Pole Equipments.

66 kV	12
33 kV	31
11 kV	1 180
Total	1 223

The Power Company provide a bulk supply in whole or part to 65 out of the 78 distribution undertakings in the areas of the combined companies, from which you will appreciate that a very large measure of unification and standardization of supply and pressure has been established in the area. The Power Company supply their associated distribution companies in bulk, and the latter provide the low-pressure distribution networks, of which there are approximately 600 in the combined areas.

System of Supply

Reverting now to the original undertaking of the parent Power Company, supply was commenced in 1905, with 3-phase generation at 11 kV and 50 cycles, this being also the working pressure of the general distribution system for bulk and power supplies. A secondary distribution system at a pressure of 2 000 volts was used in certain sparsely populated districts to deal with small-power and isolated premises: this system has not been greatly extended but still serves a useful purpose.

Low-voltage 3-phase 4-wire distribution was commenced in 1905 at 400/230 volts.

In view of their subsequent adoption as the so-called "national" systems of supply you may consider that the choice—so long ago—of these pressures, i.e. 11 kV for generation and distribution, and 400/230 volts for low-voltage supply—was fortuitous; these voltages were also used on the Lancashire Power Company's system and I believe on a few others at about the same date, and it would be fair to say they have stood the test of some considerable experience.

The phenomenal growth of the demand during and after the War called for the provision of a high-voltage transmission system as a feeder to the extensive 11-kV network of mains. At the time when this became necessary, i.e. 1924, underground cables—which were a necessity for the built-up districts in the central part of the area—were not commercially available for voltages above 33 kV, and, as later events proved, even at this voltage the original design of cable unfortunately proved to be wrong.

Although investigations into the technical requirements—based on the estimated potential load and extent of the system—indicated a much higher voltage, there was no alternative but to lay down a 33-kV system, the initial section of which consisted mainly of underground cables laid through the built-up districts of the central part of the area. With the knowledge that a higher voltage would be required later for the more remote districts, the majority of the overhead line extensions were constructed for 66 kV working pressure but were operated *pro tem.* at 33 kV.

The 66-kV system was commenced in 1929, and since that date the majority of the earlier main transmission lines have been converted from 33 kV to 66 kV. To facilitate the stepping-up, double-ratio transformers giving voltages of 66/33/11 kV were installed at main substations during the development period, and this enabled the conversion to 66 kV of over 60 miles of mains, and 6 main substations to be carried out during two week-ends.

Mains Construction

Excluding the densely populated urban areas (which have their own problems in matters of layout and construction) the majority of the extensive areas of supply in this country usually contain a variety of physical features which may introduce special methods of construction, or local conditions may exist which affect both design and construction.

In the area with which we are dealing, under the former category comes the very hilly nature of much of the area, together with many navigable and other waterways;

whilst under the latter category the highly industrialized development of the West Riding provides its problem in many forms of atmospheric pollution.

It must be admitted that the high moors of the Pennine Range give friendly shelter against salt deposits during winterly gales from the west which have actually caused trouble on their western flank; on the other hand there is no such useful barrier against the blizzards from the North Sea, of which we have had a fair share!

Overhead Lines.

The considerable distances between centres of population and industry, the extent of the area to be served, and the suitability of the open country comprising much of the area, postulated for economic reasons the extensive use of overhead lines, and this is reflected in the high proportion of this type of construction on the system.

Deep valleys have made possible long spans and an interesting example is a span of 1 925 ft. across the Calder Valley at Salterhebble. This consists of a single-circuit 33-kV line, with three S.C.A. conductors of 0·15 sq. in. copper equivalent and aerial earth wire of the same cross-section, and was erected in 1929.

This span is of interest as it crosses two County main roads, along one of which a tramway ran until quite recently, a navigable canal, a river, a main-line railway, and a branch-line railway.

The insulation consists of triple yoked strings of six 10-in. cap and pin insulators, the conductors being terminated in special cone-type clamps designed by the Company: the earth wire on this span is provided with full insulation so as to constitute a spare conductor under emergency conditions.

Another but longer span of similar construction on the same transmission line crosses the Ryburn Valley; in this case the span length is 2 368 ft.

These spans are somewhat exceptional as regards length but there are numerous other examples of spans of from 700 ft. and upwards where practically normal construction with stayed wooden poles or steel girder masts is used, the main variation being an increase in conductor clearances.

The crossing of navigable waterways frequently introduces the problem of excessive headroom and generally involves the use of very high lattice masts.

An example which was dealt with in a different way is the crossing of the River Ouse near Goole. Here the river is about 600 ft. wide and is crossed by a new bridge which includes a swing section at its northern end. High-masted craft use the river at this point, and a clearance of 120 ft. was stipulated. While it would have been possible to provide a normal bank-to-bank span, this would have involved costly piled foundations, extremely high masts, and difficult connections to the adjacent spans and substation. Incidentally the highways authority were desirous of having l.t. signalling and other circuits run from their bridge control cabin on the remote bank to the fixed side of the open bridge span. The crossing was made by means of an intermediate mast of the Company's standard fabricated type supported on the bridge steelwork. This carries, in addition to the power-line conductors (3 × 0·10 sq. in.), an aerial earth wire which acts as a catenary suspension for the highways authority's 25-core control cable.

Of the more normal overhead-line construction I propose to say very little. The results of pioneer work and experience on many supply systems and over many years, of research and investigation into design, material, and methods of construction, and of phenomena associated with operation, have all contributed to steer design and construction into well-defined and proved types suitable for the various requirements and local conditions, so much so in fact that it is not easy nowadays—as it was at one time—to recognize by the construction the undertaking to which a line belongs. Moreover, modern construction of overhead lines has been so exhaustively dealt with during the past few years in many excellent papers given before The Institution that I feel it will suffice to give you a few particulars of our past and present practice in Yorkshire.

The 11-kV lines erected in 1908 still carry the original conductors of hard-drawn solid copper, but the brackets and insulators have been renewed and their formation altered to that of the tipped triangle. Shackle insulators were originally used at angle and terminal points, as strain insulators of the modern type were not then available. An open-wire telephone circuit is run beneath the power conductors for system communications.

In these early days the Post Office had technical objections to running their circuits underground at power-line crossings, and it was common practice to carry the Post Office wires on the power-line poles. An earthed catenary suspension provides protection to highway users, and a platform guard is interposed between Post Office and power circuits. With the exception of insulators and their supporting ironwork and the modernizing of protective equipment, these crossings are substantially as erected 30 years ago.

The present standard 11-kV line on wooden poles embodies the anti-bird perch bracket which I think we may modestly claim to have originated in Yorkshire nearly 20 years ago, and which is effective in its object and avoids the use of other components which in themselves introduce additional maintenance. The tipped-triangle formation may involve a slightly higher cost for the insulator supports, but it reduces the troubles due to non-synchronous swinging and enables phase centres to be reduced, with resulting closer regulation.

The 66-kV and 33-kV lines are supported on "H" section steel girder masts fabricated from special bulb flats welded together at the makers' works, delivered in two sections and bolted with fish plates. An earlier type consisted of bulb angles and a centre flat riveted together.

These masts were designed by the Company and have been used on the system for practically all 33-kV and 66-kV lines (about 360 miles) during the past 10 years. They are particularly suitable for high-voltage lines of large capacity where the conditions admit of normal spans of not less than 550–650 ft. and have many advantages over the alternative lattice masts, such as:—

(1) Small ground area, being less than 2 sq. ft. over the concrete benching.

(2) Completely fabricated in the shops, except for section joints.
(3) Easy transportation.
(4) Plain surfaces for painting, with low maintenance costs.

They occupy very little more ground than a single wood pole and in consequence are economic in wayleave rentals as well as being much less objectionable to owners and occupiers of land than the more common types of support used on these high-voltage lines.

The design results in efficient distribution of the metal to give the combined beam and column properties, and provides a support which is sufficiently flexible to damp down vibration and to accommodate itself without collapse to any new alignment resulting from a broken conductor. They can be made in lengths up to 75 ft.

Masts of similar design and of welded construction are also used for important 11-kV lines where long spans are possible and conditions are otherwise suitable, in which case they compare favourably in cost with wooden pole construction when the price of steel is at a normal level.

The provision of an efficient foundation is an important factor in this design—as indeed it is with all forms of line support. A series of foundation designs to meet all classes of subsoil from virgin rock to marsh land has been evolved, and by careful survey and ground tests beforehand the varying conditions can be met by the most suitable type.

As to low-voltage lines, the present code of Regulations of the Electricity Commissioners exerts an influence which practically confines these to the vertical arrangement of conductors, giving the requisite protection without additional components.

The general tendency of all overhead construction is towards simplification of the top hamper, and this is particularly exemplified in the combined construction consisting of both high-voltage and low-voltage circuits on the same supports, considerable economies being obtained by operating with one phase of the high-voltage line "earthed." Successful examples of this type of construction were evolved some years ago by Mr. Fennell on the Mid-Cheshire undertaking, and more recently by Messrs. Edmundsons on their undertakings. This form of construction commends itself for the difficult economic conditions of straggling or ribbon-type villages and groups of premises widely separated.

Connections to "Live" Overhead Lines.

Jointing on "live" low-voltage underground cables has been normal practice on supply undertakings for many years, but the practice is not extensively applied to overhead lines. So far as the older systems are concerned the reason is fairly obvious, as they include many lines erected under earlier codes of Regulations which imposed arrangements of conductors and various types of guarding, making it very difficult if not impracticable to protect the linesman against live contacts or the circuits against interference.

With the present—almost universal—use of the vertical plane for conductors, and the omission of the earth wire, the problem is simplified, and in order to minimize inconvenience to domestic consumers by the frequent making "dead" of low-voltage distribution mains for new service connections, it was decided to carry out "live" line service connections.

Safety equipment and tools were devised and, as in the case of cable jointers, only men specially trained in the method and officially authorized are allowed to carry out such work. The protective equipment consists of split rubber sleeves in 30-in. lengths for placing over the conductors on each side of the poles, together with rubber hoods to cover the insulators. After fixing the sleeves and hoods the clevis and insulators for the service line are fixed on the specified phase bracket, for which purpose it is only necessary to remove the hood; the service line is then made off and by sliding the rubber sleeve along the wire the service wire is connected by a "line tap" fitting. The protecting sleeves and hoods above the connected phase are then removed, commencing at the top. A similar procedure is adopted for connection to the neutral.

Strict adherence to the regulations issued is enjoined on all the staff concerned, and the method is restricted to certain types of construction and only on the authority of a responsible engineer. The safety equipment is subjected to a monthly inspection and its condition and suitability for further service or otherwise is certified by a responsible official. The method has been in operation for only a short time and experience may show that it can be extended: for the present it is considered desirable to restrict its application.

The Life of Wood Poles.

There is little published information concerning the life of creosoted wood poles, although statements have been made from time to time that the Post Office have obtained an average life of about 30 years and a maximum of about 50 years.

It is difficult to trace the history of every pole on a large system, as deviations and alterations are made from time to time and recovered poles are used elsewhere, but it has been possible to analyse the history of several of the earliest 11-kV lines on the system. I find that out of 1 603 poles erected in 1908 and 1909 the replacements due to decay amount to 96, or say 6 %. The first replacements were made in 1932, giving a minimum life of 24 years, whilst the average life of the 96 failures was 28 years.

A further 117 decayed poles have been replaced on other parts of the system, most of them with over 20 years in service, making a total of 213 replacements out of approximately 14 000 poles on the system of the age of 15 years and upwards, or say $1\frac{1}{2}$ %.

The Commissioners' scale of depreciation for overhead lines allows a life of 35 years, and our experience seems to indicate that this component should show a reasonable residual value at the end of the specified period.

In the failures just referred to, decay was found mostly between a point about 1 ft. below ground and about 5 ft. above ground, which is the usual experience with partially buried timber. Of the 96 failures in poles 30 years old, 30 were taken from one section of line in water-logged land which is generally flooded during the winter. Organic impurities are probably present and it seems clear from this mass failure that these conditions con-

stitute a definite cause of premature decay and should be avoided when fixing the routes of lines.

Some of the premature failures were due to soft grown wood, and in a few cases inherent disease was apparent. It is difficult to detect the latter even when poles are inspected in the white state; poles in service should therefore be tested periodically by taking drillings with the special tools available, or by tapping. Poles in good clay subsoil generally show the best condition: clay is practically inert, and the excess creosote exuded from the pole when new forms a protective film which is largely retained by the clay wall.

As regards failures of wood poles under working load, it may be of interest to record that on the combined systems with a present aggregate of over 40 000 wood poles and over 30 years of experience, the failures amount to only 4 poles. One of these was a terminal pole, the stay of which broke under exceptionally heavy ice load on the line: the remaining three were decayed poles which broke under the stress of heavy gales.

Cables for Transmission and Distribution.

(*a*) *Design.*—For the generality of distribution work at the lower pressures the conventional design of paper-insulated cable usually referred to as the " solid " type meets the requirements. The results of intensive research into problems connected with higher-voltage cables during the past 10 years are being applied generally and we are undoubtedly getting better cables.

As regards the higher-voltage cables for main transmission, the 3-core Höchstädter or screened type is giving excellent service. A length of 23 miles of 33-kV cable of this type has been in service on the system for 11 years and from its earliest days has at times been loaded to 90 % of its rated maximum without failure other than faults due to external damage by spiking. The remaining 95 miles of similar cable—some of it 8 and 9 years in service—has also been entirely free from insulation breakdown.

Most of the alternative types of cable for 33 kV and over involve the use of complicated ancillary plant for which it is not easy to find accommodation and which may be costly to maintain. At the same time, research has clearly demonstrated the need to maintain the dielectric in a fully impregnated and voidless state. It therefore seems probable that before very long only those types of cable will be used for the higher voltages which provide the necessary pressure to the dielectric in order to suppress ionization. Of these new designs, those in which a gas is utilized as the pressure and/or impregnating medium give promise of good performance combined with a reasonably simple installation.

(*b*) *Operating Temperatures.*—With the issue of the E.R.A. Reports F/T115 and F/T117* we have been given further general formulae and data by which we may accurately calculate the maximum rating for practically any size of cable and for all the usual methods of laying or installation up to the limit of 20 kV. In view of the increasing use of cables for voltages above 20 kV, we hope it may not be long before similar data are available for these, although it is appreciated that with the evolution of new types, giving promise of improved performance, it may be necessary to await the results of further research and experience.

With the data now furnished there is no need for any guesswork in deciding the size of cables for the generality of distribution work at the lower voltages. The information will be of particular value for large and special cables for machine, transformer, and similar installations, which, on technical and economic grounds, call for close tolerances.

As an example of the practical application of such data, I should like to mention the case of an installation of 11-kV cables between a 30 000-kW generator and its step-up transformer at one of our power stations. The route included a variety of external physical conditions, and the size of cable was determined by calculation based on the several factors which these conditions—and the type, grouping, and arrangement of the cables—introduced. Tests carried out with the aid of thermo-couples fixed to the cable sheaths at the time of installation showed a deviation of approximately + 3 % only from the calculated temperature-rise of the cable.

While for the majority of distribution cables at the lower voltages voltage-drop is usually the limiting factor, many cables are required to carry their full load continuously. There are also occasions, e.g. under peak-load or emergency conditions, when it is necessary to exceed the continuous rating, in which case it is essential to know the safe maximum current of the cable. Under these latter conditions the intermittent rating factors given in the Report can be applied.

It is with higher-voltage cables of 33 kV and above that the question of maximum temperature assumes a greater importance, as these cables are usually the medium for transmitting large loads considerable distances between substations. By the provision at the receiving ends of suitable voltage regulators with a generous range of tappings it is possible to make full use of the copper, but regard must be had to the temperature of the cable throughout its length.

With this in mind, when installing a number of 33-kV cables on the Yorkshire system some 3 years ago provision was made for ascertaining the temperature of the cables under working conditions. This provision consists of thermo-couples fixed to the armouring of the 3-core screened-type cables at positions where normal conditions obtain, and at other positions where the subsoil, method of laying, or other conditions, are abnormal. These installations are of a permanent character, consisting of thermo-couple leads suitably protected and terminated on panels in pavement boxes or mounted in substations.

The measurement of the thermo-couple e.m.f. can of course be obtained directly with a galvonometer, but in order to eliminate possible errors in correcting for the appreciable resistance of the leads a potentiometer is used with self-contained accumulator, standard cell, and galvonometer. A vacuum flask containing crushed ice, together with connecting leads of similar material to the thermo-couple leads, and a graph to show the relation between voltage and temperature of hot junction with cold junction at 0° C. for the particular thermo-couple used, completes the testing equipment. The temperature-drop through the dielectric is calculated from the

* *Journal I.E.E.*, 1938, vol. 83, pp. 497 and 517.

heat generated in the cable and the thermal resistance of the dielectric.

Tests have been made on these 33-kV cables at intervals during the past 2 years, but the current loading has not yet been sufficient to provide conclusive evidence of the effect of the various external conditions on their ratings. It will be appreciated that the daily and weekly load cycles are of such a nature that the temperature of the cable will not reach the final value which would result if the loads were steady at the load recorded at the time of test.

From the tests carried out it seems clear that cables laid at shallow depth are more affected, and those laid extra deep are less affected by air temperature, than those laid at the normal or standard depth: also that cables laid in canal tow-paths have temperatures below normal, particularly in winter. Heating due to the proximity of adjacent cables has not had sufficient effect to show any appreciable rise above normal, thus confirming the separation distance adopted. In one case, the effect of hot-water pipes near the cables is evident, and, although the winter rating may not be affected, some restriction may be necessary in summer, or alternatively a length of lagger-conductor cable may have to be inserted.

The Figure shows the results obtained to date, the curve representing the theoretical temperature of the particular cable used on the system on the basis described.

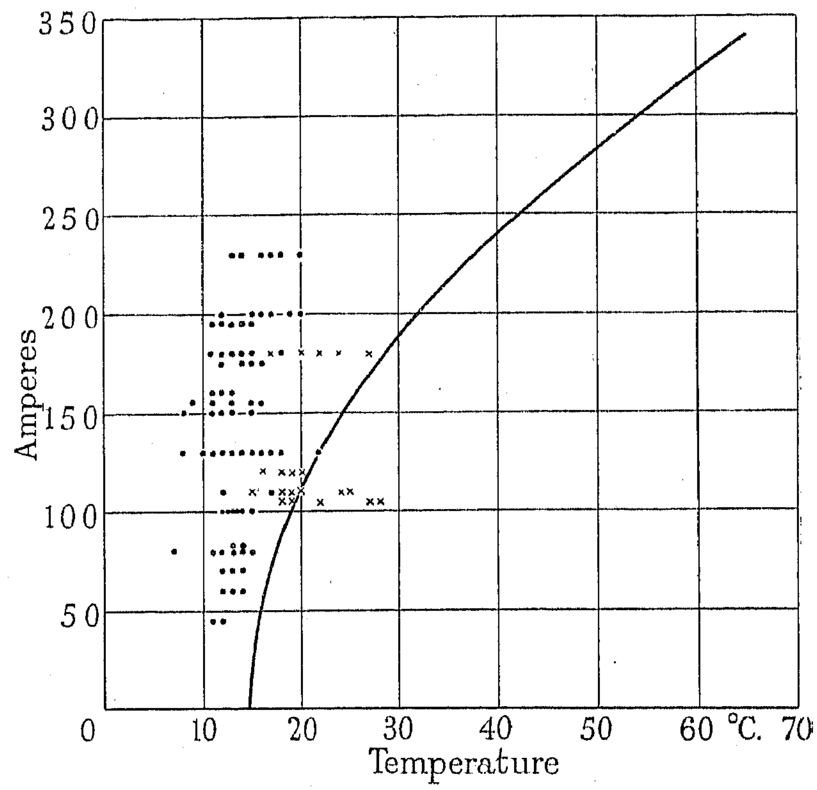
It will be noted that the majority of the readings are below this theoretical datum. An examination of the test records of these conductor temperatures shows some inconsistencies, the variation probably being due to the cyclic nature of the load and to varying air temperatures, to seasonal variation of thermal resistivity arising from changes in moisture content and temperature of soil, and to unavoidable variation in time of day and week when the tests were taken. Moreover, the loading on some of the cables has not been very high to date and slight errors in measurement will have an abnormal effect.

The readings to the right of the datum curve relate to one or two hot-spots, and show the value of the thermo-couple installation. Such information will enable these positions to be kept under observation and appropriate steps to be taken when increased loading warrants such action.

As regards further research on cables, and speaking from the user's point of view, I feel there is a real need for investigating the effect of heavy short-circuits on cables under fault conditions. We know that the recommended maximum temperatures for continuous and short-time rating under normal conditions are largely determined by the mechanical limits; there is, however, a dearth of information relating to the maximum short-circuit current density for the period of time required for protective equipment to operate, or in the event of it being inoperative due to some inherent defect.

Experience with faults on mains near large concentrations of generating plant under conditions of extremely heavy short-circuit currents points to the need for providing, on lengths adjacent to power stations, not only conductors of ample copper section for heat dissipation but possibly a more suitable type of insulating material than the conventional paper: alternatively, a reinforcing copper tape over the dielectric or the sheath might prevent the creation of permanent voids. Joints on these terminal lengths also call for special treatment: provision for abnormal expansion and for preventing excessive core movement appears desirable.

(c) *Cable Jointing.*—I think it will be conceded by most mains engineers that the present standard of design, materials, and workmanship, in cable jointing, so far as cables of conventional design and voltages up to 20 kV are concerned, is extremely good. For instance, I find from our records that over the past 10 years the average number of joint failures on 11-kV cables was 2·4 per annum: these figures relate to 542 miles of that class of cable existing at the end of the period mentioned. Ageing appears to have no influence on joint failures, if one may judge from the record of some of the oldest mains! These 11-kV cables were laid in 1904, and on the whole length of about 30 miles only 6 faults have occurred in joints over the period of 34 years.



Temperatures of 3-core 0·25-sq. in. "H" (screened) type 33-kV cables with oval conductors. Cables laid direct in ground. Rating 341 amperes with conductor temperature 65° C. and ground temperature 15° C. Curve represents theoretical temperature of cable.

...... Temperature of conductor with air not exceeding 15° C.
× × × Temperature of conductor with air exceeding 15° C.

In the mining areas of the county we experience some trouble due to ground subsidence. Expansion joints of the well-known Vernier type have been used, and although they will not save the cable under excessive ground movement they undoubtedly minimize the number of interruptions. Similar joints have also been successfully used on low-voltage pressure cables.

As regards joints on the higher-voltage cables, the record of performance on a system consisting of 118 miles of 33-kV cables containing over 1 100 joints and covering a total period of service of 12 years may be of interest. Three joints failed due to faulty workmanship, three failed owing to migration of compound, and one to the presence of deleterious matter.

In view of the limited experience with cables at these higher voltages, this total of 7 faults over the full period

of use (12 years) is not unsatisfactory and compares very favourably with published statistics on similar cables in other parts of the world. The problem of the migration of compound into the cable under the influence of the temperature cycles is one which relates particularly to the normal or solid type of cable in which the joints are usually filled with a semi-fluid compound. It is a problem that must be solved, as cables at these higher pressures usually form part of important transmission systems, and it would be neither economic nor convenient to have to top-up the joints periodically.

A jointing school is an essential complement to the organization of a large supply undertaking and provides the medium for investigation, the trying-out of new designs, and the training of jointers.

New methods are tried out in the school, and one which concerns the cutting and removal of the lead sheath may be of interest. With the issue of B.S.S. No. 480—1933—for Paper-Insulated Copper Conductors, a new class of l.t. cable was introduced and rated for voltages up to 460 volts, the cable being of the "beltless" type. This type of cable is quite suitable for straightforward street work, and as it shows a price saving of the order of 5 to 6 per cent it was decided to adopt it for such work. Due to the reduced thickness of dielectric and the absence of a normal belt of insulation, there appeared to be an increased risk of damaging the insulation in the operation of cutting and removing the lead sheath. Investigations were therefore carried out in conjunction with the cable makers, and a method was evolved in which by the use of a strong clasp knife and a pair of pliers it is possible to remove the lead sheath without recourse to the usual hack-knife and hammer. Two longitudinal cuts $\frac{1}{2}$ in. apart are first made, then two circumferential cuts $\frac{1}{2}$ in. apart at the joint centre: the small square of lead between the intersecting line cuts is then removed with the knife, after which the remainder of the $\frac{1}{2}$-in. strips can be torn off, followed by the remainder of the unwanted sheath. The method is applicable to all normal cables, with the possible exception of the very large ones with specially thick sheaths, and we are satisfied from our experience over the past 5 years that we have eliminated or greatly reduced one possible source of damage to cable during jointing operations.

Substations and Transformer Equipments

Under this heading a very large variety of designs will be found on any large supply system, ranging from main transmission substations at the highest voltages to those employed in the direct supply to power consumers and distribution networks at a primary voltage of 11 kV.

The subject is a wide one, and I propose to confine my remarks mostly to transforming units for rural and small supplies.

Kiosks.

For general distribution with underground mains, concrete kiosks are used. These are built from pre-cast concrete slabs made in quantities and stored for use as required. The only building work required on site is the grouting together of the slabs and the placing of the concrete raft and flat concrete roof. After erection the outer surface is finished rough-cast, pebble-dashed or block-lined to suit local conditions. An ornamental wood-framed and tiled roof—also a stock item—is added and the doors are of sheet steel. These kiosks are easy to transport and erect, give no trouble from condensation, and have a very low maintenance cost. They have a further advantage over the steel type in that they can be extended by the use of additional unit slabs to accommodate further switchgear when required. The simplest type accommodates an incoming 11-kV feeder and isolators, 11-kV fuses for transformer (up to 200 kVA), l.t. switchgear, metering, control for street lighting, and sundry tools.

Pole Equipments.

In addition to being standard for all rural work in which overhead lines predominate, pole equipments are being increasingly used to give supplies to isolated power consumers, pumping plants, and the like.

Transformers up to 100 kVA are supported on single wood poles, and up to 200 kVA on "H" poles. Protection on the primary side is by high-rupturing-capacity cartridge fuses of the replaceable type. L.T. control switchgear is contained in a small steel cabinet for single- or 3-phase supplies up to 25 kVA, while for larger supplies for distribution networks, where metering, street-lighting control, and several outgoing circuits, are involved, a wooden cabinet is provided which houses all this equipment, together with fuse-operating rods, spare fuses, sundry tools, and in some cases a telephone. The lower half of the door drops down and provides a dry stand.

No conservator is provided, as in our experience the extra cost of this is not justified on these small transformers; it is essential, however, that all bare "live" metal and connections should be under oil to prevent flashover in the head of the transformer. In order to reduce the risk of flashover from steep-fronted waves due to transients, a co-ordinated spark gap on the transformer bushing is desirable.

Sealing End and current-transformer Chamber.

With the increasing size of the outdoor type of circuit-breaker bushings for 66-kV and 33-kV systems, the practice of housing the M.H.B. feeder-protection current-transformers in the bushing becomes impracticable. Where such outdoor type circuit-breakers are used in conjunction with insulated cable connections, the difficulty was overcome by designing a composite cable sealing-end and current-transformer chamber, the latter consisting of a housing in which the bottom provides the usual gland for the incoming cable and the top of a seating for the porcelain insulator of the sealing end.

The chamber takes any one of the current transformers standardized by the Company for this service, and the arrangement has the advantage that the current transformers can be changed by removing the top cap, disconnecting the flexible link, and removing the porcelain; the current transformer can then be passed over the cable core. For this service the use of double-ratio current transformers avoids frequent changes on increase of load. The secondary leads of the current transformers are brought out to a small insulated panel in an external

housing, from which the circuit cables are taken through a packing gland.

Breaking-up of Streets.

The powers of public utility undertakers in the matter of the breaking-up of streets for the purposes of their Acts or Orders have been brought into prominence recently during the consideration by Parliament of a private Bill, when an attempt was made to impose additional obligations on the undertakers. Eventually a clause was agreed containing certain amendments to the provisions of the Gasworks Clauses Act, 1847, some of which are not unreasonable in the light of modern conditions. It also provides that where, as the result of road improvements, alterations to mains are reasonably required, the cost of such alteration shall be borne by the highways authority.

This principle has been previously established in another private Act—thanks to the efforts of the Conjoint Conference of Public Utility Associations, who have been striving for many years, along with representatives of the Highways Associations, to agree a general clause which would provide for this and many other matters affecting their respective interests, but on which agreement has not been reached. Valuable precedents for the future are therefore available, and now that a Joint Committee of both Houses is to be set up to consider the existing provisions of the Gasworks Clauses and similar Acts it is to be hoped that this particular question of alterations to mains will be dealt with in an equitable manner on the lines of these precedents.

The public utilities' case is a very strong one: it would be unfair that their consumers should be asked to bear the cost of road works which are carried out for the good of the community as a whole.

The deliberations of this Joint Committee, together with those of the Committee on the Consolidation of Highway Law, should provide the means for dealing with the various out-of-date provisions and deficiencies of the many statutory enactments relating to undertakers' and highway authorities' powers.

Modern developments in both highway and public-utility practice call for a code in keeping therewith. For instance, the additional powers relating to the breaking-up of streets contained in the defunct Electricity Bill of 1933–34 (most of which were subsequently embodied in the Reading Corporation Act, 1935) are very badly needed; some of these powers are already enjoyed by certain undertakers but they should be granted to all.

It is highly desirable that in any general legislation relating to the breaking-up of streets the powers and obligations should be uniformly applied to all statutory undertakers and—if I may dare to suggest it—the Post Office. We recognize the national importance of the Post Office communication plant (Parliament also has looked after this aspect very well, judging by the very ample protection given to the P.M.G. in the Electricity Supply Acts!), but in at least one respect the distinction at present existing is the cause of many difficulties which I feel could be removed.

For instance, the P.M.G. is under no obligation to serve notices on other statutory undertakers except when alterations of undertakers' plant are required. It is true that a measure of collaboration exists and, within my personal experience, very friendly relations generally with Post Office engineers, but this is insufficient, and it would be to our mutual advantage to have a complete interchange of notices of intention to carry out works.

Damage to plant and difficulties in siting works in congested streets are not infrequent occurrences, and as evidence of this I would mention that over the past 10 years 28 % of the faults on our underground system have been due to external causes. In some of the earlier years it reached the high proportion of 44 %, but this figure has been improved as the result of friendly collaboration with highway and other authorities, including the Post Office.

The serving of formal notices of intended works is at present almost "one-way" traffic—with electricity undertakers as the only entrant: this is largely due to the vague and apparently little known provisions of Section 18 of the Electric Lighting (Clauses) Act, 1899, which are more often honoured in the breach than in the observance. I am quite sure that many of these cases of external damage could be avoided by uniform obligations in the matter of notices.

Another means for removing difficulties between the various undertakers would be the allocation of a standard position in streets for the various mains and pipes. This practice has been in operation for over 10 years in respect of all new main roads in the City of Leeds. Admittedly this can only be entirely applied to new roads, but with the extensive road widenings now in progress its application so far as practicable to existing roads would in time bring about improved layouts and savings in several directions, and would avoid difficulties in siting new works.

As regards other general powers for electricity undertakers, codification of the Acts is an urgent need to meet the requirements of an industry which is advancing phenomenally, and it seems altogether wrong that undertakers should have to obtain additional powers of general application through the costly procedure of a private Bill.

Wayleaves

Wayleaves and consents for overhead lines continue to be the biggest source of delay in rural and general development. Nothing has been done to rectify the position arising out of the judgment in the Pitt case. The result is that when the Minister gives an overriding consent, no pecuniary terms are fixed and the onus is on the owner and occupier to seek compensation after the line is erected. In some cases after the Minister has given consent, and prior to the erection of the line, the owner enters into an agreement, usually on the terms of the undertaker's standard form, in which case the undertaker need not act on the Minister's award. In others, no action is taken by the owner to secure compensation, nor will he enter into an agreement. An anomalous position is thus created—the undertaker has erected the line and is paying no rentals, with the consequence that a grievance exists which makes it more difficult to secure other wayleaves from the same owner.

The suggested standard form of wayleave agreement between undertakers and the land-owning interests appears to be dormant. There is much to be said for

reviving this proposal, as with the added experience over the past few years it should be easier to agree standard terms and conditions to meet the varied types of construction and local conditions; moreover, the advantage of a voluntary settlement is obvious. In any new general legislation, however, the ambiguities and deficiencies of Sections 21 and 22 of the 1919 Act should be dealt with.

Conclusion

My remarks have been mainly in retrospect as I felt that information on current practice, special construction, and in particular of long-period service results on one of the oldest of the larger supply systems, might be of interest and in some respects indicate the advance that has been made in distribution technique during the period covered.

As to the future, and without wishing to digress into the political sphere, it seems clear that some measure of unification of distribution is essential, as the present conditions are worsened by the recent revision of local government areas which has resulted in overlapping of powers of supply in some of these areas. You will remember that under these County Review Orders the powers of electricity undertakers are preserved, and I could give you instances where three undertakers now have powers of supply in one local-authority district. I have no doubt that similar cases exist in other parts of the country. Such conditions are bound to create difficulties and cause confusion in the minds of the public.

With regard to distribution generally, the experience gained over many years, together with the enormous amount of research and investigation during recent years, has evolved technique and efficiency of a high order. At the moment we are having to meet increasing costs, among them rates—which now amount to about 8 % of the working expenses—and it is more than ever necessary that we should seek new economies in design and construction in order to reduce the cost of distribution and so enable us to give better and cheaper facilities to the public whom we serve.

Acknowledgments

I wish to thank Mr. W. B. Woodhouse, the managing director of The Yorkshire Electric Power Company, and the Company itself, for permission to publish the information relating to the Company's undertaking.

ARGENTINE LOCAL CENTRE: CHAIRMAN'S ADDRESS

By C. G. BARKER, Member.*

"THE BENEFITS OF TECHNICAL EDUCATION"

(*Address delivered at* Buenos Aires, *23rd May*, 1938.)

The primary object of The Institution being the advancement of electrical engineering technique, we are fundamentally interested in the technical training of the engineer, and though we often have papers on that subject we hear comparatively little of the results of this education in the early years of his career.

The main object of this Address is to give some idea of the after effects and advantages of technical education during the first 10 years of the engineer's career.

I do not intend to discuss technical education in detail, or the merits or demerits of the inclusion or exclusion of certain subjects in the curriculum, though a few remarks on the subject may not be out of place. The course should be as broad as possible, for the obvious reason that the majority of students do not know initially the particular field of engineering where they will ultimately take root, and, even if they did, a general education would probably be of more value to them than over-specialization. The training should curb at the outset a man's desire to be over-individualistic and should ingrain in him the great value of co-operation and team work, while encouraging his initiative and creative abilities.

I remember the time when Professor Armstrong used to supply newcomers to his chemical laboratory with a liberal allowance of sea water to boil down. During the slow process of filtering the residue after the salt had crystallized out they were asked to invent means of hurrying up the filtration. The small response to this showed that the standard of inventiveness was not very high. The filtrates were then pooled in a common jar and small quantities of rarer substances were obtained from them, all of which was very instructive and perhaps exciting in view of the prospect of finding a trace of gold, but it was probably many years later that the majority of us realized that this was a very ingenious initiation into the art of team work.

The curriculum in the old days included many and varied subjects, the one notable exception being "telephony." I believe this has been remedied since, but nevertheless in that branch of the electrical industry there are many opportunities to be grateful for an all-round training, and although the telephone business is usually considered to belong to the light side of electrical engineering I shall endeavour to give you some examples later on to show that it is not so light.

An investigation was recently carried out by the Old Students' Association of one of the London University technical colleges (hereafter referred to as the College) into the early part of the careers of the graduates, with a view to assessing the commercial value of the training given, and it is thought that the results of this investigation will be of interest at least to our younger members, especially in view of the generous efforts (to which I shall refer later) that are being made locally to put English technical education within reach of the more able members of the rising generation.

During the 50 years' life of the College, some 4 000 men have studied there for periods of 2 to 4 years, and records are available of at least part of the careers of 2 800 of these who obtained their diplomas. This total is divided into 1 800 who remained in England, 576 who went to the Dominions and Colonies, 225 who went to foreign countries (especially the Americas), and 243 who gave their lives during the War or whose careers were otherwise ended.

The 50 years were divided into 5 ten-yearly periods, and it was found that the percentage of students obtaining employment abroad dropped from 35 % to 16 %, showing that the openings had greatly diminished. We are particularly aware of this in the Argentine, where local technical education has made rapid strides, where *industria nacional* is the order of the day, and where legislation calls for such a high proportion of Argentine personnel in public service companies and others. In this connection it may be stated that the importation of trained or semi-trained engineers in the Telephone Company is now at a standstill. To offset this, students are taken on from the Escuela Industrial, where they enter at 13 to 14 years of age and pass through a 7-year course and emerge at the age of about 20 years with a knowledge which, as far as I have been able to judge, compares favourably with that of a second-year student at home. A 4-year course is now arranged in the Company for these students in the Engineering Department, where they are taught all branches of the work by experienced engineers and given practical demonstrations in the field. A classroom is set aside for the purpose, and classes are given several times a week in the Company's time. The rest of the students' time is spent in routine work assisting more experienced men in the preparation of plans, estimates, and specifications.

The Old Students' association of the College under discussion recently sent out a questionnaire to 1 300 old students, only 23 % of whom answered. Results were tabulated showing the agency through which employment was first obtained, subsequent changes of employment during the following 10 years, renumeration obtained, the effect of the War on their careers, etc.

With regard to the last-named, the report says that "many freely admit that the war broadened their out-

* Cia Union Telefonica, Buenos Aires.

look, inured them to responsibility, and gave them opportunities they would otherwise not have obtained, but to many it brought ill-health and suffering and was a serious setback in their careers. Compared with other sections of the nation the percentage of those who served in the first line was possibly smaller, engineers and technically qualified men being relegated to positions where their experience and knowledge could be utilized in providing lines of communication, munitions of war, etc."

As regards the finding of employment, there does not seem to have been any great amount of unemployment and it might be taken roughly from the returns that supply and demand of young engineers have been fairly well balanced.

Figures are also given of average salaries obtained during the 10 years, and adjustments for the cost-of-living index. These would form an interesting basis for comparison with, say, the results obtained by engineers who served a premium apprenticeship at one of the big engineering works or with ex-students of the Escuela Industrial, though I have been unable to obtain information of this class. " Civil engineers, especially those working with contractors, and therefore called upon to move about the country, seem to get more pay than electrical or mechanical engineers employed in large firms. Yet the latter are easily able to attract men and keep them. 'Safety First' seems to exercise some influence, and men remain in a department of a big organization, becoming rather narrow specialists with little or no prospect outside the firm they are in. Those who have enterprise and change their jobs from time to time have, no doubt, to face risks, but in the end do better."

" Those who come out of the College with its Diploma, and usually also with a university degree, ought to be in a position to keep themselves on their professional earnings within a year or so after leaving college. The figures suggest that not till, at any rate, the fourth year is the average salary sufficient to enable them to do so. It is possible that the competition of scholarship holders, who are frequently without private resources and are therefore compelled to accept whatever offers, has contributed somewhat to the decreased remuneration of young engineers which prevails to-day. Manufacturers during the last decade have been through hard times, but recently things have improved, and there is no doubt that to a large extent the improvement is due to the technically trained employee, who should share in the increased prosperity. This point is emphasized by the much higher scale of pay obtained by those on the business side of these concerns.

" It is easy to transfer business experience from one firm to another, and success on the commercial side is more readily recognized by the business men who control these undertakings. The technically qualified men, even those of outstanding ability, are relatively in a weak position. The trend in this direction cannot be considered satisfactory, as in the intense competition there is between nations we cannot afford to fail in the encouragement of scientific and technical qualifications. It is now fairly generally recognized by employers that research work is a good investment, but it would appear that those engaged on it, for lack of business instinct, are not adequately rewarded. It may be that their interest in their work enables them to regard this with equanimity.

" When a deliberate choice can be made at the age of, say, 18, between a college course or a practical course, the advantage altogether lies with the former. On the other hand, there is equally no doubt that much benefit is to be derived from spending the long summer vacation in getting practical training either in works or on construction. At no time does there seem to have been any difficulty in getting employment after leaving college, but comparatively few were so placed that they had a definite job waiting for them.

" Engineers during the first ten years have now few opportunities to do work of an original character, and the contributions which they make to professional literature are neither numerous nor important. Chemists and physicists are in a somewhat better position, but as the years have passed since men first came out of the 'College,' there is a marked decrease in their output of accepted papers by the recognized scientific and technical societies. The explanation probably lies in the great increase in team work under more senior men, in the extensive application of research to specific problems of commercial interest, and to the lack of command of equipment to carry on such work by junior men."

A relatively large proportion of students at the College in question obtain scholarships, the proportion in 1935 having been 180 out of 400. The total value of these scholarships was some £16 000 per annum and they range from £300 down to £20 per annum.

While on the subject of scholarships, I should like to refer to the Inchcape Memorial Scholarships in Engineering at Glasgow University for sons of British residents in Argentina, which are administered locally by our Centre of British Engineering and Transport Institutions.

These Scholarships were established in 1934 by Mr. and Lady Effie Millington-Drake as a memorial to Lady Effie's father, the late Earl of Inchcape, both as a tribute to the British community in this country and to provide for the training of engineers for the development of reciprocal Anglo-Argentine trade.

Briefly, two scholarships were established to be offered every 3 years for a trial period of 9 years (or 6 scholarships in all), at the end of which time the scheme is to be reviewed so that the donors may consider whether it is achieving its proper object.

The Scholarships are known as a " major " scholarship of £250 and a " minor " scholarship of £150 a year, both for 3 years, the latter being intended for candidates whose parents can furnish the extra £100 a year to make up the £250 required for their sons' maintenance.

While the scholarships are nominally for 3 years with a view to gaining the C.P.E. (Certificate of Proficiency in Engineering), should the candidates have the necessary educational qualifications they are admitted to the course for the degree of B.Sc. in Engineering, in which case the scholarships are extended to 4 years for this purpose.

Candidates must be between 16 and 19 years of age.

In the long summer vacations Inchcape scholars go for practical training as apprentices in prominent engineering establishments.

Three scholarships have already been awarded, one for a degree course. There is also a plan for "honorary" scholars whose parents pay all the fees but who have the full advantages of the carefully devised and perfected scholarship system with the direction, control, and advice of the special tutor, etc.

Applications, to be received by the 31st May, are now being received for one of the "minor" scholarships.

The scholarships are governed by trustees in England, and the Buenos Aires Selection Committee consists of His Majesty's Ambassador as Chairman; and the Chairmen of the Centre of British Engineering and Transport Institutions, The British Chamber of Commerce, the St. Andrew's Society of the River Plate, and the British Society. The Secretary to the Selection Committee, to whom I am indebted for these notes, is the General Secretary of this Centre of British Engineering Institutions.

I am glad to have this opportunity to put on record this Institution's sincere appreciation of the great generosity of Mr. and Lady Effie Millington-Drake in founding these scholarships and thus providing a unique opportunity for the sons of British residents here to go through a thorough engineering training. This is but one of their many efforts to knit still more closely the ties which bind our country to the great Argentine Republic.

It is of the highest importance that full opportunity should be given to the rising generation to contribute to the progress of the arts and sciences, and while many benefit from the scholarships now available there is evidence that some students through keeping their noses too near the grindstone, or through pecuniary difficulties, come out of the college suffering from what is termed "an inferiority complex," due in no small measure to isolation from their fellows in all that contributes to growth of character. Some overcome this disadvantage but others suffer from it permanently, and in consequence are not able to pull their full weight in after life.

It is a well-known fact that personality and character, a pleasant manner, and easy address, must be added to mere knowledge for the attainment of success.

The report also hints that some of the students later gave up engineering and started on other activities, so I should like to quote a few words of Mr. Henry Ford with regard to failure. He says:—

"The habit of failure is purely mental and is the mother of fear. This habit gets itself fixed on men because they lack vision. They start out to do something that reaches from A to Z. At A they fail, at B they stumble, and at C they meet with what seems to be an insuperable difficulty. They then cry 'Beaten' and throw the whole task down. They have not even given themselves a chance really to fail; they have not given their vision a chance to be proved or disproved. They have simply let themselves be beaten by the natural difficulties that attend every kind of effort. More men are beaten than fail. It is not wisdom they need or money, or brilliance, or 'pull,' but just plain gristle and bone. This rude, simple, primitive power which we call 'stick-to-it-iveness' is the uncrowned king of the world of endeavour. People are utterly wrong in their slant upon things. They see the successes that men have made and somehow they appear to be easy. But that is a world away from the facts. It is failure that is easy. Success is always hard. A man can fail in ease; he can succeed only by paying out all that he has and is. It is this which makes success so pitiable a thing if it be in lines that are not useful and uplifting.

"If a man is in constant fear of the industrial situation he ought to change his life so as not to be dependent upon it. There is always the land, and fewer people are on the land now than ever before. If a man lives in fear of an employer's favour changing towards him, he ought to extricate himself from dependence on any employer. He can become his own boss. It may be that he will be a poorer boss than the one he leaves, and that his returns will be much less, but at least he will have rid himself of the shadow of his pet fear, and that is worth a great deal in money and position. The elimination of fear is the bringing in of security and supply."

To return to the question of the heavy side of telephony mentioned above, let us take some illustrations to show the need for broad education in the case of the telephone engineer. All these are taken from the *Bell Telephone Quarterly* of January, 1938.

(1) A catenary suspension of nearly $\frac{1}{2}$ mile in length, carries thirteen 10-pin crossarms fixture and open wires across the Gila river in Arizona. The "H" towers are 75 ft. and 100 ft. high and contain some 75 000 lb. of steelwork.

(2) Ice blocks are sometimes used to lower heavy ducts and cable runs. The joints of multiple tile duct are comparatively fragile and usually suffer many breakages when being lowered with chain hoists or jacks. In one case, at Flatbush Avenue, Brooklyn, the ducts were lowered in 48 hours through the melting of the ice, with negligible breakages.

(3) The 8-storey, 11 000-ton building housing the general office of the Indiana Bell Telephone Co. in Indianapolis was pushed 52 ft. further back on its lot and turned through 90°. 600 people in the building carried on as usual, elevators ran up and down, gas, water, electricity, and telephone facilities were maintained, and a pivoted drawbridge provided entrance and exit.

(4) Across the Harlem river, New York, there is a 614-ft. tunnel made up of 7-ft. diameter pipes with walls $1\frac{3}{4}$ in. thick which were placed in a trench, giving 27 ft. draught from mean water-level. This was assembled in 72-ft. lengths weighing 50 tons, and was lowered into position by floating derricks. After divers had sealed the joints with lead it was covered with 18–26 in. of concrete and pumped dry. It was then filled with standard vitrified clay conduit to a total of 206 ducts into which cables can be drawn as required. The 72-ft. section at each end is curved.

These are good examples of the progress made by electrical engineering. This progress compares very favourably with that made by any other professions, and for this we have largely to thank the efficiency of the technical colleges and the research laboratories of the large electrical undertakings.

WESTERN CENTRE: CHAIRMAN'S ADDRESS

By H. S. ELLIS, Member.*

"THE ELECTRICITY SUPPLY INDUSTRY"

(*Address delivered at* BRISTOL, 10*th October*, 1938.)

I propose in this Address to deal with that branch of electrical development with which I am best acquainted and to endeavour to put before you some of its achievements and also some of the difficulties which are hampering its fuller development. Turning to my copies of the *Journals* of The Institution of about 30 years ago to see what was being discussed then, and in the hope of finding whether anyone had been bold enough to forecast the lines on which the industry would be likely to develop, I came across the name of Kelvin and wondered what he had to say. Mr. Highfield's paper entitled "Transmission of Electrical Energy by Direct Current on the Series System" was under discussion and Lord Kelvin said that he had never swerved from the opinion that the right system for long-distance transmission of power by electricity was the direct-current system.

Lord Kelvin did not go so far as to prophesy anything, but in quoting the following words of Lord Rayleigh, uttered some years previously, he did, I submit, uphold a prophecy. It appears that Lord Rayleigh had said that he rejoiced to see the use of alternating current coming in, "Because the whole world will now learn the subtleties of electrical science, which they had no chance of learning before . . . and, after that, they will come back to the continuous current."

Whether that prophecy will ever be fulfilled remains to be seen, but the fact is that the 3-phase alternating-current system continued to gain in popularity all over the world, whereas, so far as I am aware, the other made little or no headway at all despite the advantages (both technical and financial) claimed for it by its advocates.

If one turns to the Central Electricity Board's Tenth Annual Report (1937), one will find that the British grid system alone comprises approximately 4 180 miles of transmission lines, 2 938 miles of which operate at 132 kV and the remainder at 66 kV and lower voltages, all on the a.c. system, and that 137 selected stations having a total installed capacity of 7 653 570 kW were already coupled up to it. Furthermore, as the Electricity Commissioners' Returns show, whereas the total capacity of generating plant installed in the stations of authorized undertakers in Great Britain in 1937 was 8 398 241 kW, only 217 238 kW, or 2·59 per cent of it, represented d.c. plant and, also, that of the 8 557 000 consumers connected only 1 100 000, or barely 13 per cent of them, were supplied from d.c. systems. It would appear, therefore, that notwithstanding the advantages claimed for the d.c. system, both for transmission and distribution purposes, it seems fairly safe to assume that the public supply of electricity will continue to be afforded on the a.c. 3-phase system, and that in cases where direct current is required for special purposes, such as the electro-deposition of metals, battery charging, and other special purposes—such as exclude the use of alternating current—motor-generators, rotary convertors, and static rectifiers, will continue to be used in conjunction with the a.c. system.

Continuing my search I came across the late Sir John Snell's (then Mr. John Snell) paper on the "Cost of Electrical Power for Industrial Purposes,"† and I was much interested to note the similarity between some of his remarks and the principles outlined 11 years later in the 1919 Act, which established the Electricity Commissioners (of which Sir John became Chairman), and which was designed to enable electricity supply undertakers to increase the scope of their activities and to effect some co-ordination of electricity supply systems, as recommended by the Committee presided over by Sir Archibald Williamson, who recommended "that the parochial system of generation and distribution should give place to more economical methods involving wider areas of distribution." After dealing at some length with the difficulties which many of the smaller boroughs had to face in extending their plant to cope with the demand of industrial power users on economical lines, Sir John enlarged upon the idea of centralized generation of electricity and the consequent shutting-down of local generating plant.

Notwithstanding the 1919 Act and the further Act of 1922 which supplemented and amended its provisions in relation to the Commissioners, Joint Authorities, and Companies, and the fact that some of the municipalities and most of the larger companies, whose operations extend over very wide areas, had already clearly demonstrated their ability to effect some co-ordination of electricity-supply systems, it was not until the 1926 Act was passed and the Central Electricity Board became established that the generation of electricity for public supply came to be co-ordinated on a national basis, and it was about 10 years after then that the Electricity Commissioners reported that the grid was in full operation (throughout the year 1936) in the areas of Central Scotland, Mid-East England, South-East England, and South-West England and South Wales; and, as from the 1st January, 1937, in South Scotland.

The Board stated in their Tenth Annual Report (1937) that the two major economies to be looked for from the grid are (1) the capital saving arising from the reduction in the operation of generating plant necessarily held in

* West Gloucester Power Company, Ltd.

† *Journal I.E.E.*, 1908, vol. 40, p. 288.

reserve and which by the end of 1937 was estimated at approximately £17 millions, or more than half of the capital expended on the construction of the grid and its extensions and reinforcements to-date, and (2) the annual saving on revenue account due to the reduction in coal consumption per unit arising from the concentration of production at the more economical stations. Unfortunately, although the fuel consumption in 1937 was nearly 17 % less than under the conditions of independent operation prevailing in 1932, which, had the level of fuel prices ruling in 1935 been maintained, would have resulted in a saving of £1 800 000, there was a corresponding increase in the price of coal, with the result that the average cost per unit sent out in 1937 was only about 3 % below the 1932 level. As the price of coal has continued to increase it seems highly probable that this small saving will disappear entirely during the current year. However, we in the electricity-supply industry have the satisfaction of knowing that such increases probably affect our competitors to a much greater extent than ourselves and our consumers.

Thermal efficiencies exceeding 27 % (based on units sent out per annum) have already been achieved in certain of the larger stations, as compared with rather less than 20 % in the case of 424 stations in operation in 1937, and it therefore seems reasonable to assume that further substantial savings will be made in the future.

The Electricity Commissioners' Returns show that progressive improvement in steam-power-station equipment and practice have resulted in the average fuel consumption per unit generated being reduced from 3·42 lb. in 1927–28 to 1·47 lb. in 1936–37. The lowest average fuel consumption recorded over a period of 12 months was 0·92 lb. per unit generated, representing an output of 2 485 units per ton of fuel consumed and a thermal efficiency of 27·70 % (on units sent out), which I understand is the highest on record. These results were obtained by the London Power Co. at their Battersea station, with a maximum load of 233 050 kW and 1 148 million units sent out, or 56·3 % load factor. It is perhaps worth mentioning here that in the Central Electricity Board's Report for 1937 special reference is made to extensions in selected stations comprising 646 250 kW of generating plant and boiler plant having in the aggregate an evaporation of 7 488 500 lb. per hour, and particular reference is made to Battersea.

Other extensions are given in Appendix II of the Board's report, including turbo-alternators ranging in size from 15 000 kW to 75 000 kW, and boilers up to 350 000 lb. evaporative capacity. I mention these figures more particularly because they indicate very clearly, I think, the trend of modern power-station practice. Still higher steam pressures are being tried out in the United States, and it was stated in the electrical Press a few months ago that the most outstanding recent advance in this direction was the decision of the American Gas and Electricity Co. to install as an extension to the plant of one of its subsidiaries a turbo-alternator set to operate at 2 500 lb. pressure and 940° F., which, they claimed, would be "more than an experiment."

It is interesting to note the higher thermal efficiencies attained by such plants, but it would be equally interesting, I think, if we could know more of their effect on repairs and maintenance costs and on "outages" (the availability of plant), and whether, having regard to these things and the higher capital cost entailed, they are worth while. After all, thermal efficiencies are not the whole story, and in these days of very large units and high pressures and temperatures it is the total cost that really matters and, therefore, comparisons should be made on this basis rather than on thermal efficiency alone. Fortunately for me, my Address is not open for discussion, but I hope that my remarks may prompt one of our members to write a paper on the subject, as I feel sure it would prompt a lively and instructive discussion, and perhaps produce a simple formula on which proper comparisons of power-station performances could be based in the future.

When one considers these facts and that during the same period the load factor of the generating stations of the public authorities and companies taken collectively was of the order of 35·5 %, it is not difficult to imagine the scope there is for further substantial economies in generation and transmission costs as the result of the greater use of the grid and other transmission lines. It has been claimed that the incidence of the cooking load, which is developing very rapidly throughout the country, will tend to decrease load factors, but I have sufficient faith in the industry to feel satisfied that ways and means, such as off-peak load control of thermal storage for cooking, water-heating, air-conditioning, refrigerators, and similar uses, will counteract this tendency, and that load factors will increase, rather than decrease, in the future. It is unfortunate that the present system of supply precludes the use of storage batteries, as these would not only assist in increasing individual load factors, and the load factor of the country as a whole, but would ensure a greater measure of safety against interruptions of supplies.

The rapid development of the overhead system for transmission and distribution purposes in rural areas has made supply systems much more vulnerable to the forces of nature than they were formerly, and although much time and money have been expended on the development and use of devices for the better protection of our systems from the ravages of the elements, and particularly lightning, much remains to be done if we are to retain, as we must do, "continuity of supply" as one of our principal maxims.

This will be appreciated by those of you who are connected with supplies in rural areas and who have good reason to remember the blizzard of February, 1933, when conductors in many parts of the country, and particularly in South Wales and South-West England, were reported to have been coated with snow and ice to a thickness of 3–5 in., and when considerable sections of transmission and distribution networks and Post Office lines were brought to the ground. Fortunately, such phenomena are rare in this country, but as we have no guarantee against their recurrence we must take every precaution to ensure that when they do occur their effect will be limited to the greatest possible extent consistent with sound economical practice. As on this, and other similar, but, fortunately, less-disastrous, occasions, the failure of the Post Office lines

added to the difficulties of supply engineers, it is good to know that many of these lines are now being laid underground. Many of the difficulties which supply engineers have to contend with would be solved if their lines also could be laid underground, but there seems little prospect of the supersession of overhead lines by cables to any general extent, in spite of the great improvements that have been made in connection with the latter for e.h.t. working, as their cost prohibits their use except in urban areas and in rural districts in the vicinity of aerodromes and other special cases where circumstances preclude the use of overhead lines.

The three essentials to the ultimate success of electricity distribution are competitive prices, a steady voltage, and a continuous supply. We cannot expect to retain the goodwill of consumers, however reasonable the charges may be, if we fail in these last two essentials. We managed to do so in the past to a great extent because, in the majority of cases, where electricity was used only for lighting and, perhaps, an electric iron, which fortunately retains its heat for considerable periods, interruptions which occurred in the day-time, unless they were of long duration, were seldom noticed by consumers. But the use of electricity for other services, such as cooking, heating, water-heating, wireless, television, electric clocks, and daylight signs, has developed to such an extent that low voltage, more particularly in the case of cookers, and interruptions, are readily detected, and consumers will no longer tolerate them. It is necessary, therefore, that supply undertakers should provide distribution systems which will be adequate, in every respect, to ensure full and efficient supplies to their consumers.

In the *Beama Journal* (1937, vol. 41, p. 97) it was recently pointed out how wireless helps to increase the demands for electricity, an increase of 33 % in the lighting consumption of the household being mentioned.

According to figures adduced by M. Deuch of Brussels, relating to the annual consumption of electricity per wireless set in various countries, it appears that the British Broadcasting Corporation provides by far the highest estimate, i.e. 87 kWh per wireless receiver as compared with 54 kWh in Belgium, France, Holland, and America, and 40 kWh in Germany. The number of wireless licences issued in Great Britain in 1937 was approximately 8 800 000, as compared with 8 557 175 consumers connected to supply systems, a truly remarkable achievement for the wireless industry when one considers its comparatively recent birth. Although it is not stated what proportion of these wireless sets were connected to the mains, it is reasonable to assume that a very large number of them were, and that, as and when the public supply of electricity becomes available to the majority of premises in this country, as it undoubtedly will within the course of a very few years if the present rate of development is maintained, wireless in Great Britain will have reached its saturation point with a consumption which I have estimated at approximately 1 000 million units per annum.

Improved forms of construction embodying the use of suspension insulators and, in the case of pin insulators, sloping brackets, have done much to eliminate bird troubles from overhead lines, and it is very rarely, e.g. when exceptionally large birds (such as swans), whose wing-span exceeds the spacing of the conductors, come in contact with conductors, that such troubles occur at all nowadays. Great improvements have been made in the design and manufacture of insulators and insulator pins to free them from troubles due to climatic conditions, and the adoption of protective devices combined with the duplication of supplies, either by ring mains or double-circuit lines, has also done much to free supplies from interruptions. If, therefore, something further could be done to render them less vulnerable from the ravages of the elements already referred to, I am satisfied, as the result of long experience, that the overhead system should be capable of affording quite as satisfactory supplies in rural areas as cables have done in the more densely-populated urban areas, and, furthermore, they have advantages, such as low cost, flexibility, and accessibility for service connections, which cable systems do not possess to the same extent. I have rather stressed this question of continuity because to my mind it is a matter of very considerable importance in these days when so many of the more progressive supply undertakers have facilities, such as hire and hire-purchase schemes, whereby their consumers are encouraged to extend the use of their supplies.

It is regrettable that electricity distribution is being hampered to an increasing extent by delays in connection with the granting of wayleaves under Section 22 of the Electricity (Supply) Act of 1919. This difficulty arose partly because of the disappointment felt by many land-owners and farmers when they came to realize that notwithstanding the fact that they had granted facilities for overhead lines to be erected across their land they were unable, because of the nature of the lines, to obtain supplies from them, but mainly, I think, because of the judgment given in the King's Bench Division of the High Court in December 1932 (in what is now familiarly known as "the Pitt Case") when it was held, amongst other things, that the words "Terms, conditions and stipulations," in the section whereby the Ministry of Transport is empowered to give consent to the construction of overhead lines subject to "such terms, conditions and stipulations" as he considered just, did not include pecuniary terms; and that claims in respect of compensation for wayleaves ought to be determined by arbitration under Section 17 of the Electric Lighting Act, 1882; whereas, previously, it had always been taken for granted that the section gave the Minister, as the words seem to imply, full power not only to grant wayleaves but to settle the terms as well.

The question of wayleaves has been the subject of much discussion by the National Farmers' Union, and anyone desirous of pursuing the matter further should refer to the Union's Year Book for 1938, where the whole matter is dealt with in considerable detail. For my present purpose it must suffice for me to quote the following paragraphs which appear in the Year Book under the heading "A Few Don'ts":—

"Don't think the electricity undertakings can have it all their own way; they are sometimes bluffing.

"Don't agree to a line passing over your garden or

pleasure ground. In such cases the undertaking should buy the land it wants.

"If your land has an immediate building value, don't sign a voluntary wayleave form at all, not even the National Farmers' Union—Central Board Form. The undertaking should buy the land or go to arbitration.

"If the Minister of Transport has purported to fix your compensation, don't omit to take advice as to your position. He has no power to do it.

"Don't omit to ask the advice of the County Secretary of the National Farmers' Union if you are doubtful as to any point in connection with a wayleave agreement presented to you for signature."

I do not want to weary you with a long dissertation on the anomaly created by the decision in the Pitt case, but I feel sure that many of you who are more particularly concerned in the development of electricity distribution in the more sparsely populated areas of the country will agree that the position of the Minister of Transport so far as this question of wayleaves is concerned is most unsatisfactory. As you know, the McGowan Report contained a recommendation that Section 22 "should be amended to give effect to what was understood to be its original intention, namely, that the Minister of Transport when granting compulsory wayleaves should also by statute be enabled to fix the wayleave rentals," but, nevertheless, the Government's proposals on electricity distribution (as outlined in the White Paper), which were based on the recommendations of the McGowan Committee, contained no reference whatsoever to the subject. Whether the omission was made deliberately for political reasons I do not know, but I submit that it will be unfortunate, to say the least of it, if in the new legislation which is contemplated the Minister of Transport is not empowered to fix wayleave rentals and compensation in all cases where agreement between the parties is not reached. It may be argued that in spite of the present position we need not suffer undue delays in proceeding with our extensions, and that all we have to do is to serve notices and await the Minister's consent to our applications, as indeed we have to do in any case, and then settle the pecuniary terms of the wayleave after consent has been granted. But this involves delay and expense, and, after all, it should not be forgotten that the majority of land-owners, and their tenants, are reasonable people who, if they are properly approached, are usually willing enough to facilitate extensions and who would strongly resent formal notices being served upon them (what some of them have described as "high-handed action"), and that it is only the small minority who stand out and make such a course necessary.

I fully expected that I should have something to say to you about the new Electricity Distribution Bill, about which we have heard so much and seen so little, but it is now quite apparent that it will fall to the lot of one or other of my successors to do that. It is now nearly 3 years since the McGowan Report was published, and some 18 months since the contents of the White Paper which outlined the Government's proposals for the reorganization of electricity distribution throughout the country, and which were to form the basis of the Bill, became known, and it is not surprising, therefore, that there have been complaints that the delay in proceeding with the matter is holding up development in certain areas. Fortunately, that has not been my own personal experience, as development in the West Gloucestershire Power Co.'s area is proceeding more rapidly than ever before.

Although the primary objectives which the McGowan Committee sought to achieve (e.g. higher efficiency of distribution; standardization of voltages, systems, and tariffs; reduction of cost of electricity to consumers; and the wider availability of supply), and which formed the basis of their recommendations, seem to have met with general approval, considerable differences of opinion arose regarding the method of achieving them. For instance, on the one hand the smaller municipalities and companies alike appear to have strongly resented the recommendation that they should be absorbed by "the larger and more efficient undertakings" and, on the other, the municipalities as a whole, although acknowledging the good work done by the companies, strongly objected to the differentiation in the proposed terms of purchase of municipal and company undertakings. It seems unfortunate that so much prejudice and ill-feeling should have been created by the words "larger and more efficient" and "smaller or less efficient" which appear here and there in the proposals, because I do not think that they were ever intended to be taken as meaning that because an undertaking happens to be small it is necessarily inefficient and should, therefore, be absorbed. To my mind the words are perfectly clear and there should have been no doubt as to their meaning. Whatever may be the outcome of the discussions there have been since the Government's proposals became known, and notwithstanding the remarkable development of the industry during the decade 1927–1936, when units sold to consumers increased from 6 580 millions to 16 803 millions, it cannot be denied that there is room for improvement in the organization of the industry as a whole, and it may be that the delay referred to, and the further delay which it is reasonable to assume will arise owing to the present international situation, will afford electricity undertakers an opportunity of getting together and doing by mutual agreement what they otherwise may be compelled by statute to do.

The Benevolent Fund

In conclusion I want to make a special appeal, not only to you who are present to-night, but to every member, no matter what his grade may be, to support the Benevolent Fund to the utmost of his ability. If only you could realize, as I did when I attended my first meeting of the Benevolent Fund Committee in London last week, how much our efforts are needed and appreciated by those who are in the unfortunate position of having to call upon The Institution for help, and with what care the grants are made, I feel sure that this further appeal to your generosity would not go unheeded.

NORTH MIDLAND CENTRE: CHAIRMAN'S ADDRESS

By J. W. ATKINSON, I.S.O., Member.*

"THE INSTITUTION: 1872–1888"

(ABSTRACT *of Address delivered at* LEEDS, 11*th October*, 1938.)

The present session of The Institution will include the 50th anniversary of that red-letter day—20th December, 1888—when our predecessors changed its name from "The Society of Telegraph-Engineers and Electricians" to "The Institution of Electrical Engineers"; and I hope you will agree that it is appropriate to spare an hour in order to look back and bestow what, after all, can be but a mere glance at the infancy and youth of the undertaking of which we are all proud to be members to-day.

It was in 1871 that a small band of enthusiastic workers in the field of telegraphy decided to form "The Society of Telegraph Engineers," and the first meeting was held on Wednesday, 28th February, 1872, under the Presidency of Dr. C. W. Siemens. After expressing thanks for his election, he said:

"Our future prosperity will be influenced in a great measure by the direction in which we shall start upon our pilgrimage. Let us hope, therefore, that our joint efforts may lead us in the direction of true scientific and practical advancement.

"But before we set out upon our labours it behoves us fairly to consider whether there is need or scope for a Society of Telegraph Engineers. Is Telegraph Engineering not a branch of Civil Engineering, and do not all our proceedings therefore fall within the legitimate sphere of action of the Institution of Civil Engineers? Or if we meet with difficult questions in physical or mathematical science, is not the Royal Society or Section A of the British Association open for us to discuss them, or may we not go before the Institution of Mechanical Engineers with any purely mechanical question? Is it desirable, indeed, it may be urged, to take a branch from the parent stem and to cultivate it separately; shall we not degenerate thereby into 'specialists,' or what may be called 'fractional quantities of scientific men,' and this in the face of the patent fact that the further we advance in scientific knowledge (whether pure or applied) the more clearly we perceive the intimate connection between its different branches, and the impossibility of cultivating one without constantly reverting to the others.

"In answer to such allegations we may fairly assert that we do not intend to become 'specialists' in the narrow sense of wishing to confine the range of our knowledge to the phenomena and appliances which have an immediate application to our professional objects. We are, on the contrary, sensible to the fact that in order to master those *special* branches of knowledge thoroughly we shall have to travel into adjacent fields and build our practice upon the widest possible scientific foundation. But our time is limited, and, although the great principles of nature may be understood generally by one person, their applications are infinite, and all we may hope to do is to attain to a general scientific basis, and with it to devote our energies vigorously to the details of one or two branches of applied science. . . .

"We may, therefore, safely conclude that a Society of Telegraph Engineers is necessary for the more rapid development of a new and important branch of applied science; I further maintain that such an Institution is desirable in order to afford Telegraph Engineers frequent opportunities of meeting each other in friendly intercourse, and of impressing them with the conviction that their united action will be advantageous to the material interests of all. . . .

"Problems of pure electrical science meet the telegraph engineer at every turn, the methods of testing insulated wire, of determining the position of a fault in a submarine cable under various circumstances, or of combining instruments so as to produce recorded messages by the mere fluctuation of electrical tension in a long submarine conductor, are problems worthy of the most profound physicist and mathematician. On the other hand, there is hardly a problem in electrical science that is not of practical interest to the Telegraph Engineer; and . . . I am of opinion that we should not exclude from our subjects questions of purely electrical science. The phenomena of electrification and polarization, of specific induction and conduction, the laws regulating the electrical wave, the influences of rise of temperature on conduction or the potential force residing in a coil of wire of a given form, when traversed by a current, involve questions belonging just as much to pure physical science as to the daily practice of the Telegraph Engineer, and would at any rate be inseparable from our proceedings."

At the First Annual Meeting on 11th December, 1872, the Council reported that the membership had increased from an initial total of 110 of all classes (i.e. Foreign Members, Ordinary Members, Associates, and Students) to 353.

The subjects of the papers read during 1872 were: Automatic Telegraphs; The Progress of Sea Telegraphy; The Application of the Calculating Machine of M. Thomas de Colmar to Electrical Computation; A Modified Form of Wheatstone Bridge; The Electrical Ignition of Explosives; Military Telegraphs; Lightning and Lightning Conductors.

In addition to these papers and full reports of the discussions, the *Proceedings* of the Society contain (in Vol. I) "Original Communications" on telegraph and related scientific matters, and also "Abstracts and Extracts" from British and foreign scientific journals, and it is clear that from the outset the latter features were valued highly by the membership.

During the period from 1872 to 1880, scientific pro-

* North Eastern Region, G.P.O. (Leeds).

gress, particularly in the study of electricity and magnetism, and the stimulus to increased practical use of the knowledge available, led to papers and discussions which appealed to many who were not concerned, or only remotely so, with the problems of the telegraph engineer; and recognition of this fact caused the Council in its Report for the year 1880 to say: "The Report of last year also referred to an intended proposal to make some addition or alteration to the existing title of the Society with the view of indicating more clearly that its Members are not confined to those who follow the profession of Telegraph Engineering, and that its mission is to assist in the advancement and development of *every* branch of Electrical Science.

"The question of what the alteration or addition should be, has been most carefully and anxiously considered by your Council, and after mature deliberation they have come to the conclusion that the object in view would be attained by adding to the present title the words 'and of Electricians.' . . .

"As the matter is to be brought before a General Meeting of Members this evening it is unnecessary for the Council to say more than that they have most carefully weighed the merits of every possible form of alteration which would meet the required end without prejudicing the original title under which the Society has attained its present satisfactory position among scientific bodies, and they leave the final decision to the members themselves."

The proposal was adopted by the General Meeting held on the 22nd December, 1880.

I am not in a position to assess the effect of the change of title on the scope of the work undertaken by the Society during the next few years—this aspect of the matter will no doubt be dealt with in the forthcoming "History of The Institution," for which we shall be indebted to Mr. Rollo Appleyard. It is clear, however, from even a cursory examination of the *Proceedings* that the period from 1880 to 1888 was one of great activity and I feel that the change must have proved of value in dealing with such important matters as Fire Risks; Electrical Nomenclature and Notation; the need for a Standardizing Laboratory; and the question of amended legislation in respect of electric lighting—to all of which I refer later.

I turn now to some of the "landmarks"—as I see them—after 1880.

The first of these landmarks had its origin in the advent of electric light and took the form of a Memorandum, dated 21st June, 1882, with the title: "Rules and Regulations for the Prevention of Fire Risks arising from Electric Light." It was superseded by a similar print, dated 11th April, 1883, and this by an expanded Memorandum, dated 11th April, 1888. It is known to most of us that this subject was one of acute and prolonged controversy and that the solution was reached eventually by the issue of Board of Trade (now Ministry of Transport) Regulations and the I.E.E. Wiring Rules. As regards the period to the end of 1888, the papers contributed by Mr. A. C. Cockburn on the 8th December, 1887: "Safety Fuses for Electric Light Circuits, and on the Behaviour of various Metals usually employed in their Construction" (1887, vol. 16, p. 650) and by Mr. W. H. Preece, on the 10th May, 1888: "Fire Risks and Fire Office Rules" (1888, vol. 17, p. 478)—will be found to be worth perusal from the standpoint of appreciating some of the difficulties of the electrical engineer of that time.

The second landmark I would mention is Prof. Andrew Jamieson's paper on "Electrical Definitions, Nomenclature and Notation" read on the 14th May, 1885 (vol. 14, p. 297), regarding which the following extracts from the Reports of the Council for 1885 (vol. 14) and 1887 (vol. 16) are of interest:—

1885.

"As announced at the Ordinary General Meeting of May 14th, the Council, looking to the importance of a uniform system of electrical nomenclature and notation, which formed the subject of Professor Jamieson's paper read on that evening, resolved to appoint a comprehensive and influential committee to consider it.

"They have satisfaction in reporting that, in addition to the assistance of a large number of members of the Society, they have obtained the co-operation of nearly all the professors of physics at the Universities and leading public colleges of the United Kingdom, as well as that of Mons. Blavier, the president, and Mons. E. Hospitalier, the Secretary, of the French committee formed for a similar purpose.

"The general committee appointed a sub-committee of its members to consider and report upon the best course to be pursued in dealing with the subject, and the latter have already made their recommendations as to the different heads under which the chief work to be undertaken should be done.

"These recommendations have been approved and adopted by the general committee, who have appointed a sub-committee to carry out the important work therein indicated."

1887.

"The Committee on Electrical Nomenclature and Notation have been assiduously summarizing the various terms in general use in Electrostatics, Electro-Kinetics, Electro-Magnetism, and Electrotechnics, and have made considerable progress towards moulding together a coherent system, but some time must yet elapse before their Report can be submitted."

The conclusion of this matter carries us much beyond 1888 and might well form the subject of a separate address.

The next of my landmarks was the paper contributed on the 26th November, 1885, by Dr. (now Sir) J. A. Fleming "On the Necessity for a National Standardizing Laboratory for Electrical Instruments." The author's line of approach to the subject is best indicated by reproducing the quotation from Sir John Herschel used by him as a text, together with his opening paragraph and his summing up:—

"If every scientific inquirer observed only for his own satisfaction, and reasoned only on his own observations, it would be of little importance what standards be used, or what contrivances (if only just ones) he employed for this purpose; but if it be intended (as it is most important they should) that observations once made should remain as records to all mankind and to all posterity, it is

evidently of the highest consequence that all inquirers should agree on the use of common standards, and that these should not be liable to change by lapse of time.

"Unless we transmit to posterity the units of our measurements, such as we ourselves have used them, we in fact only half bequeath to them our observations. This is a point too much lost sight of, and it were much to be wished that some direct provision for so important an object were made" (Sir John Herschel).

"In the above quotation from his famous 'Discourse on the Study of Natural Philosophy,' Sir John Herschel gives emphatic and elegant expression to the general idea which it is proposed in this paper to consider, with special reference to the quantitative study of the sciences of electricity and magnetism, and especially with reference to the world-wide practical and industrial applications of them, in which the employment of accurate measurement forms the basis of all success. . . ."

"The foregoing remarks have probably sufficed to outline in a very rough way the present difficulty and some proposed remedy. I conclude by casting into the form of five propositions the notions above thrown out, not in any way intending them to be dogmatic statements of what ought to be accomplished, or the way to do it, but simply as fulcra round which your discussion can turn, and they are as follow:—

"1. The measurement of electrical phenomena and effects has now become such a practical and everyday operation that it is highly desirable that unity of operations should be secured in practice as well as theory.

"2. That in order that this should be the case, certain actual acknowledged standards of reference or apparatus should exist, which should be to electricity what the Greenwich mean solar standard clock is to all timekeepers, or what the standard yard or pound is to length and mass measurement.

"3. That this can perhaps best be attained by the establishment of a national electrical standardizing laboratory as above described.

"4. That action in this matter should be taken by the Society of Telegraph-Engineers and Electricians as representing practical science, in conjunction with the British Association Committee on Electrical Standards.

"5. That the Council be requested to give the matter their consideration, with the view of seeing if there is any practicable method of meeting these requirements, and, if need be, to confer with the members of the British Association Committee on Electrical Standards and the Council of the Royal Society, or other acknowledged authorities, to see if it commends itself to those bodies as a scheme of practical utility or of national advantage to have undertaken."

A valuable discussion followed, as the result of which a resolution was passed unanimously desiring the Council to consider the best means for giving effect to Dr. Fleming's proposal: some of the difficulties encountered are indicated in the following extracts from the Reports of the Council for the years 1887 (vol. 16) and 1889 (vol. 18):—

1887.

"The Committee appointed to consider the question of the establishment of a Standardizing Laboratory for Electrical Apparatus have given due attention to this important subject and have made certain recommendations, which, as they involved the raising of a considerable sum of money, it was not thought desirable by your Council to attempt at the present moment to carry out."

1889.

"Your Council being convinced that the establishment of a Standardizing Laboratory by the Board of Trade would be found indispensable for the proper administration of the Electric Lighting Act, and having received a communication from the Electrical Trades Section of the London Chamber of Commerce, calling attention to the importance, from an industrial point of view, of the standardizing of electric measurements, re-appointed the Standardizing Committee, for the purpose of considering the matter and of drawing up a scheme for such a laboratory, with estimate of the cost.

"After this had been done, two joint meetings of the Committee and a consultative Committee of the Electrical Trades Section of the London Chamber of Commerce were held, and the draft scheme, as then finally approved, was adopted by the Council, and forwarded by them to the Board of Trade.

"A joint deputation of the Institution and of the London Chamber of Commerce subsequently had an interview with the President of the Board, to urge the adoption of the scheme.

"There is every reason to hope that this recommendation, which had already been partially adopted, will eventually be fully carried out, and thus render unnecessary any other standardizing establishment, which, however well organized, and under whatever influential auspices it might be created, could scarcely expect to meet with the general recognition which a Government establishment must necessarily command."

The remainder of the story is to be found in the establishment of the National Physical Laboratory and, I suppose, the British Standards Institution.

The last of my landmarks is the action taken to secure amendment of the Electric Lighting Act, 1882, culminating in a Petition to the House of Lords in April, 1886. (The amending Bills, to which the Petition referred, were subsequently dropped for other reasons.)

It will be understood, I am sure, that, in addition to the four matters I have mentioned specifically, many others of great and growing importance came under consideration during the period 1880–1888; but it is impossible on this occasion to do justice to the numerous papers and communications which can rightly be claimed as milestones on the road of progress. Telephony, Electric Lighting (generation, distribution, and economics), Electric Traction, and Medical Electrical Treatment, all attracted contributions of high value: so, also, the question of the education and training of engineers in the telegraph and newer fields of work regarding which advice and guidance were tendered by (among others) Sir William Thomson (afterwards Lord Kelvin) and Professors Ayrton and Perry.

We come now to the final change of name, and I cannot do better than turn again to the records.

Firstly, an extract from the Inaugural Address

delivered by the President, Mr. Edward Graves, on the 12th January, 1888:—

"It is almost impossible to express the variety of ways in which the action of electricity is utilized. Their name is legion, and they are ever multiplying. Communication between distant places was the first widely extended purpose to which it was practically put. Originally its operations were confined to points separated by land only. Then intervening rivers, channels, seas, and oceans were successively crossed, until now nearly the whole earth is bound together by submerged chains—a kindly bondage that is another name for union. One ocean only—the Pacific—remains uncrossed, and the barren distinction will hardly be much longer preserved. One country of importance only—the Empire of China—has hitherto been reluctant to encourage the lightning messenger, but that reluctance appears to be on the verge of disappearing.

"Another most prominent utilization of electricity is for the purpose of illumination. First practically discovered by Humphry Davy, its powers in this direction were successively made practical by Wylde and De Meritens, Pacinotti and Gramme, and by many eminent scientists of later date. Electric lighting has passed through many stages. Differing from telegraphy, it needed a longer period of trial and experiment after its commercial application began; and it is, of course, exposed to the competition of other illuminants ever seeking, by new methods, to lessen its superiority. Economy of production is, perhaps, the great necessity for its complete development. As the light of brilliance, health, and beauty, its claims are universally acknowledged; but the commercial problem can hardly be said to be yet completely solved, although the steps taken in that direction give promise of a satisfactory solution being not far off: the problem of distribution is becoming understood. . . .

"Electricity is also utilized to an increasing extent as a safeguard to the lives of the toilers in our coal mines charged with explosive gases. As yet it is somewhat in an uncertain stage in this respect—its use is proved, the desirability of its employment recognized, and efficient instruments for the purpose devised, but practice is yet needed to remove the difficulties in the way of its general adoption, to overcome the inertia that blocks its path. . . .

"Thus it is clear to me that in the facts detailed, lies the strongest justification for the proposed alteration in the name of our Society. In the summary of electrical operations which I have put before you I have given the largest space to the electric telegraph and its results. I am justified in so doing, because the telegraph is the most nearly completed of all the branches into which the laws of electricity are directed. No doubt there is still room to improve its processes, but its pioneer work is done, and it is scarcely possible that the future can yield more than progress, however important, in details. When the Society was first founded, 'Telegraph Engineers' was a fitting name, as it was only in telegraph engineering that any considerable number of the followers of the science we are considering were actively engaged. 'Telegraph Engineers' are still the most numerous units in our body, but from the force of circumstances they can no longer be said to be the special representatives of its character. 'The Institution of Electrical Engineers' is a title comprehensive enough to include all devotees of the science; no class of worker is singled out for undue prominence, no class is by implication excluded."

Next, an extract from the Report of the Council for the year 1888 (presented 13th December, 1888):

"The replies received to the circular issued by the Council in February last for the purpose of gauging the opinions of members of all classes as to the proposal to change the name of the Society, fully bore out the expectation of the Council, having practically amounted to a unanimous approval. The necessary legal steps have therefore been taken to enable the Society to assume on the 1st of next month the new title of 'The Institution of Electrical Engineers.'"

Then, a copy of the Minutes of a Special General Meeting (20th December, 1888):—

"At a Special General Meeting of Members held at the offices of the Society, 4, The Sanctuary, Westminster, on Thursday, December 20th, 1888—Mr. Edward Graves, President, in the Chair—

"The Secretary read the notice convening the meeting.

"The President explained that it would be necessary to take the resolutions which were confirmed on the 22nd November, as having been passed only on that day, and he now moved that the said Special Resolutions be now confirmed, viz.:—

1. "That the name of the Society be changed to 'The Institution of Electrical Engineers.'

2. "That the office of Honorary Secretary be abolished, and that the Articles of Association be altered by omitting all reference to the Honorary Secretary in Articles 36, 38, 40, and 43."

The motion, having been seconded by Mr. Alexander Siemens, was carried unanimously.

The President then moved the following special resolution, viz.:—

"That the Regulations of the Society of Telegraph-Engineers and Electricians, as contained in their Memorandum and Articles of Association, be altered by substituting the name 'The Institution of Electrical Engineers' for 'The Society of Telegraph-Engineers and Electricians,' and also by substituting the word 'Institution' for the word 'Society' wherever the same respectively occur in the Regulations."

"The resolution, having been seconded by Mr. C. T. Fleetwood, was carried unanimously."

And, lastly, an extract from the Inaugural Address delivered by Sir William Thomson (afterwards Lord Kelvin) on 10th January, 1889, as the first President of "The Institution of Electrical Engineers":—

"My first duty is to give you my warmest thanks for the great honour you have done me in electing me to be the first President of the Institution of Electrical Engineers. Fourteen years ago, when the three-year-old Society of Telegraph Engineers honoured me by appointing me to be their President, the Society numbered 570 members; it now numbers 1 500. It is gratifying to us to think how that young Society has grown, and how successful it has been. . . .

"The Society of Telegraph Engineers has grown not

only in membership, but in the extent of its province, from the time of its foundation until now. It became the 'Society of Telegraph-Engineers and Electricians' a few years ago, and now the more properly representative title of the 'Institution of Electrical Engineers' has been adopted. The original name included only telegraphy, but that was not then the only application of electricity to engineering. There was electro-metallurgy. Electro-metallurgy and telegraphy were the two, and I think, the only two, branches of practical science to which electricity had then been applied; but since that time we have a vast augmentation of the field. We have telephony; we have electric transmission of power. The Society of Telegraph Engineers will recollect Sir William Siemens's introduction to it of that great subject of the electric transmission of power on a scale of practical usefulness. I think we may safely feel that to the Society of Telegraph Engineers in a large measure is due that practical development of electricity. We have now power electrically transmitted through factories to drive separate machines by separate motor dynamos; we have electric haulage and electric tramcars; we have the application of electricity to naval and military purposes; and last, not least, we have the application of electricity to electric lighting. With all these grand subjects of applied practical science for our province, I think the Institution of Electrical Engineers may feel that it has a great and noble dominion.

"But we must not forget that the province of the electrical engineer necessarily touches upon that of the civil engineer. When fourteen years ago I gave my Inaugural Address, I endeavoured to impress upon engineers and architects that architects made a great mistake in not being engineers—in not qualifying themselves as engineers, and doing the work of engineers—that architects do not do their duty to their clients in not being engineers and understanding the engineering of their own works, and making engineering science, particularly the dynamics of engineering, an essential part of the training of an architect. It is not necessary to make any animadversion, I think, upon electrical engineers in this respect. Electrical engineers know well that they must, before all, be engineers. They must be engineers, and they must learn electricity.

"To young persons who have a taste for electrical machines (and who that is young has not a taste for electrical machines, and sparks, and flashes, and aurora borealis artificially made, and the smell of ozone—sulphur and phosphorus we used to call it!—which is one of the pleasing reminiscences of one's youth in working with electrical machines?) a word of advice may be useful. Every young person who has a fancy for electricity thinks he would like to be an electrical engineer. They think electrical engineering is all ether and electricity. Now I have continually to impress upon anxious fathers and mothers that their boys must condescend to learn something of gross ponderable matter, and that electrical engineering is not confined to ether and electricity, but mechanics also is an essential part of the subject. It is, I think, an important practical point this—that the electrical engineer, or the youth or aspirant to that honourable profession, ought to learn mathematics and dynamics after having obtained the elements of a good general education. He ought to learn mathematics and dynamics well. Then a good deal of chemistry and regular mechanical and civil engineering should all be learnt; and electricity learnt besides. It may be said juvenile life is too short. I do not think it is. I think if the other subjects are well learnt, electricity may be learnt in a few months. I am perfectly sure that if the youth is qualified in other departments, the mere addition of electricity to the education of a competent engineer will not take so very long a time as might be imagined, and that the merely educational part of the work will not be protracted unduly by adding electricity to the branches learnt in general engineering. I do not mean to say that if electrical engineering is the branch adopted, there is not an endless and prodigious field of electricity proper in which the worker will learn every day of his life, though he lives for more years than any person present. I wished just to make these few remarks in the beginning, because they do seem to me of some practical importance, and worthy, therefore, of being put in the front of the Address I have to offer as first President of the Institution of Electrical Engineers."

I have mentioned that the initial membership of the Society of Telegraph Engineers totalled 110, which increased during the first year to 353. At the end of 1888, the total was 1 500, whilst the report of the Council for last year shows a total of 18 252. This expansion has been accompanied, as you know, by the establishment of 8 Local Centres and 7 Sub-Centres in Great Britain and 2 Local Centres abroad, also by the establishment of the Meter and Instrument, Transmission, and Wireless Sections, and 9 Students' Sections.

We are indebted, heavily and equally, to those who, from 1871 to 1888, laid and strengthened the foundations, and those who, since 1888, have guided the building of the superstructure. I have appended a list of the Presidents during the former period and with their names I want to couple one other, namely Major (later Colonel Sir) Francis Bolton, who, with Captain (later Major-General) C. E. Webber, took a leading part in the formation of the Society of Telegraph Engineers and for some years acted as Honorary Secretary and Editor of the *Journal*.

LIST OF PRESIDENTS FROM 1872 TO 1888.

1872. Dr. C. W. Siemens, F.R.S.
1873. F. I. Scudamore, C.B.
1874. Sir William Thomson.
1875. Latimer Clark, F.R.S.
1876. C. V. Walker, F.R.S.
1877. Sir Frederick Abel, Bart., F.R.S.
1878. Dr. C. W. Siemens, F.R.S.
1879. Lieut.-Col. Sir John U. Bateman-Champain, R.E.
1880. Sir William Preece, K.C.B., F.R.S.
1881. Prof. G. Carey Foster, LL.D., D.Sc., F.R.S.
1882. Major-General C. E. Webber, R.E.(Ret.), C.B.
1883. Willoughby Smith.
1884. Prof. W. Grylls Adams, F.R.S.
1885. C. E. Spagnoletti.
1886. D. E. Hughes, F.R.S.
1887. Sir Charles T. Bright, M.P.
1888. Edward Graves.

SCOTTISH CENTRE: CHAIRMAN'S ADDRESS

By W. J. COOPER, Member.*

(*Address delivered at* GLASGOW, *11th October*, 1938.)

Each succession to the office of Chairman, carrying with it, as it does, the obligation or the privilege of giving an Address, brings with it an increasing difficulty in the choice of a subject of general interest because of the extent to which specialization of practice has taken place in the electrical branch of the engineering profession.

I have decided to address you, briefly, not on any branch of the work which the engineer does, but rather on the relationship of the engineer, in his corporate capacity, to the community in which he lives.

However inadequately I may be able to handle the subject, it will at least have the advantage of being topical since, as you are aware, the engineering Institutions have set up a joint Engineering Public Relations Committee.

Not only are the engineers concerning themselves as to how they stand with the public but so also are the men of science and the men of healing, as evidenced by their recent discussions and pronouncements when gathered together in conference under the auspices of the British Association and the British Medical Association.

To stand high in the esteem of one's fellow men is a worthy aim. In the background of the mind of the individual, although rather ill-defined and not often expressed, there has always been a recognition of the fact that the two vital issues in life are, first, the relationship of the individual to the Infinite, whatever his conception of the Infinite might be, and secondly, the relationship of the individual to his fellow men.

What is implied by the use of the words "Public Relations" when used by a group in the community? Taken literally they can only mean a recognition by the group of the existence of, or the need for, some kind of relationship with the community, and it can be inferred that they also express a desire to establish a good relationship between the group and the community, so that it would appear that the Joint Committee already referred to will have for its purpose the creation of good public relationship.

Probably from quite material motives, and for obvious reasons, political groups in the community have always been keenly aware of the need to establish good public relationship, but it is only within the last two decades or so that economic and industrial groups have been giving collective consideration to this important issue, and it is now significant that we have the professional groups, normally very specialized in their corporate interest, entering collectively into the consideration of a problem which, up to the present, has been treated as a matter quite personal to the individual. It can reasonably be assumed that neither the groups which have already tackled this question, nor the groups now about to consider it, have approached or are approaching it entirely on ethical grounds, but it is likely that the more closely we come to a true appreciation of the conditions necessary to the establishment and maintenance of good public relationship, the more clearly will the ethical basis stand out.

What are the conditions necessary to the establishment and maintenance of good public relationship likely to be? They would appear to be, first, the importance to the community of the work which the group does, secondly a recognition and acknowledgment by the community of the importance of such work, and thirdly, but perhaps most important of all, how trustworthily or with what degree of equity the work of a group is made available to the community for its betterment.

Engineers as a group present the same interesting diversity of personality as do most groups. The general availability of a liberal education enables the engineer to display at least an average intelligence, and on moral grounds I would suggest that he is likely to have at least an even chance. These rather casual observations are made so that it may be quite clear that engineers, as a group, will not consider themselves as cast from a special mould. As a matter of fact any attempt to assess the relative values of individuals or groups within the contemporary social structure merely confirms the complete interdependence of a modern community. The work of the scientist and engineer is ultimately given expression to through the labour of the hewer of wood and the drawer of water, and conversely the standard of life made available to the hewer of wood and the drawer of water is likely, to a great extent, to be dependent on the work of the scientist and engineer, provided the community lives within a social structure in which its well-being can be freely evolved.

Before speaking of the work of the engineer I should like to say that I am thinking of that work in its widest sense. In modern engineering practice the engineer is to a great extent the interpreter of the work of the scientist and research worker. In the work of the engineer there must also be included the training and technical education of those who are to carry on his work, and not by any means of least importance is the work of the engineer in the market-place.

As to the importance of the work which the engineer does for the community, it is not unreasonable to say that the pace of social and economic progress is determined by engineering achievement. Has not man emerged from his primitive state by the use of the road, the bridge and the viaduct, by the use of the fulcrum and the lever, and by the use of the wheel and the crank?

* Hamilton Electricity Department.

From these have come the mill, the pump, the loom, the engine, and the machine in its multiplicity of form, and with these man has in turn been enabled to cull from the vast storehouse of nature and turn to his uses, the conserved energy of millions of years of sunlight. From the amber distaffs of the women of Syria down through the centuries there has now come to man's use that manifestation of energy in its most refined and most universally applicable form, electricity. The continually improving technical perfection of the work of the engineer has contributed in no small measure to the power of modern man to transport himself over the earth and through the air with the speed of a projectile, to span the great oceans in a few fleeting days, to wing his words with the speed of light from one hemisphere to the other, and to see and hear far beyond the human sense of sight and sound, That sweeping generalization would alone seem to indicate that the work of the engineer is of vital importance to the community and that if it be so accepted the first condition towards the deserving of, or creation of, good public relationship has been established.

But does the community recognize and acknowledge the importance of the work of the engineer in the creation of its general well-being?

Spectacular engineering achievement has good "news value"—the opening of a great bridge, the launching of a great liner, the establishment of new speed records on land, sea, or air—and generally the work of the engineer in its more arresting form is without doubt brought before the community and noted, but the community does not, I fear, see the work of the engineer from day to day in the food it eats or in the clothes it wears, nor for that matter in any of its multiplicity of needs. The community's most intimate contact with its needs is in the price it pays for them, but in the journeyings of these needs through the tortuous ways of the market-place they seem to acquire such an enhanced value, made evident in the price, that the work of the engineer in making the need available is almost completely hidden.

It would, therefore, seem that the engineer in his corporate capacity may have a duty to the community to keep it informed as to the work which he does from day to day for the community's ultimate betterment, so that the community in its collective citizenship may be able to assess properly the value of the work of the engineer and, most important of all, prevent its misdirection to uses of destruction which might ultimately arrest, if not destroy, the civilization which man has so laboriously built up.

To assume the responsibility of keeping the community informed might be a first step in the creation of conditions suitable to the establishment of good public relationship, but the form of contact would necessarily require to be on a plane higher than blatant advertising or cunning propaganda. It would appear that the form of contact must be educational rather than propagandist, since the purpose of such contact would have the object of helping the community *how* to think of the work of the engineer and should not set out to tell the community *what* to think of his work. A well-established and intimate contact with the public on an educational, if not on an ethical, basis would not only enable the community in its collective capacity of citizenship to prevent the misdirection of the use of the engineer's work, but would also enable it to assess such work in its true value. Through what medium can such contact be made by the engineer in his corporate capacity with the community? The value of space in the Press is now so enhanced that the financial resources of the engineering Institutions are not likely to be able to obtain access to that space, but if the work of the engineer could be presented in popular form it might be possible to obtain access to this medium in some measure. Contact on an educational basis by means of the screen would, of course, be effective but is also likely to be beyond the resources of the engineer in his corporate capacity, but the medium of broadcast holds great possibilities so long as the contact is based entirely on ethical or educational grounds. Perhaps an extension of the idea lying behind the Faraday Lecture is about the only form of contact with the public which the engineering Institutions could at present sustain.

It has already been suggested that perhaps the most important condition necessary to the establishment of good public relationship between a group and the community would be a condition dependent on how trustworthily or with what degree of equity the work of a group is made available to the community for its betterment. Before proceeding to discuss this aspect of the problem it might be well to consider the functions of the engineer in a modern community. Prof. Dewey of America, speaking recently of the development of economic structure, referred in the following order to the engineers, the managers, the technicians, and the artisans, presumably inferring that the function of the engineer is to provide the ways and means by which economic development can proceed, leaving the managers with the technicians and the artisans to make "a kirk or a mill" of the application of the work of the engineer. If this is the function of the engineer it is difficult to see in what way the engineers in their corporate capacities can further the creation of good public relationship, and it may be that this assessment of the function of the engineer accounts for the recent tendency in some engineering organizations to place the executive management in the hands of an officer, who need not necessarily have scientific or technical skill. In this connection I should like to remark that the qualification for executive management is found more in the personality of the individual than in his professional accomplishments, but on the other hand I see no reason why the normal diversity of personality existing in the engineering group should not produce engineers with this qualification necessary to executive management.

What is it that has awakened the professional groups to the need of giving consideration to this question of public relationship? In all probability, though not expressed, it arises from a corporate realization of the inability of the present social and economic structure to convey to humanity, in its fullest sense, the benefits which the work of the professional groups can give to the community. Unfortunately, it would seem that the present social structure segregates the community into three main groups, the group which owns or controls access to natural resource, the group which owns the tool,

and the group which uses the tool, and it is useless to try to evade a recognition of the conflict of interest which this segregation sets up. Ownership of natural resource would seem likely to be determined, even in this advanced age, by means of force, but the apparent conflict of interest as between the owner of the tool and the user of the tool is, to some extent, reconciled in contemporary social structure, through the machinery of conciliation which has been set up in many of the organized groups of the community. There still falls to be considered, however, the influence of the present social and economic structure in this complex business of exchange of goods and services. So far as the work of the engineer is concerned it cannot be gainsaid that the existing social or economic structure fails to transfer to the community the fullest benefits which could be derived from the engineer's work. Production of goods and the physical means of their distribution has far outrun the capacity of the existing economic structure to effect their exchange.

Have we not in recent years been burning coffee and wheat and tipping fish, garnered by the arduous labour of man, back into the sea, not because we were producing more of these vital needs than we could consume or more than was necessary for the community's well-being, but simply because the existing means by which these needs are exchanged could not, or would not, sustain the transaction? Are we not now restricting the production of coal, the production of milk, and many other commodities through the process of what we call rationalization? In the market-place is it not now the practice to acknowledge openly the unwisdom of competition, and in fact in the exchange of certain commodities legal enactments now exist completely prohibiting competition? Has not the scientist and the engineer made available to the community a productive system of almost incalculable capacity, and is not this productive system confined within a social or economic structure, which limits the power of the community to use the productive system now available, to an extent much beyond the limit of mere subsistence and the most elementary culture? I suggest that it is really this maladjustment in the existing scheme of things which has awakened the interest of the engineering Institutions to this question of public relationship, but it is only necessary for me to have touched on this highly controversial subject to show that any approach by the engineering Institutions to this aspect of the problem would probably disrupt the Institutions and divert them from the true purposes for which they were established and for which they are needed.

It appears to me that an approach to this aspect of the problem of creating the conditions necessary to the establishment of good public relationships must necessarily remain a matter personal to the engineer in his individual capacity or in his capacity of citizenship, but nevertheless, it would seem that a modification of the existing social and economic structure must be brought about in order that it may come into line with the community's ability to create a higher culture. If it is right to assume that this maladjustment of the economic structure is at the bottom of the desire to consider public relationships then the Engineering Public Relations Committee will have served a good purpose if it does nothing more than awaken in the engineer, in his individual capacity, the need of becoming more politically conscious. To become politically conscious is not necessarily to be consumed by a desire to propagate some ideology, but rather that the engineer should be able, as Lord Weir put it in his address to the International Engineering Congress, "to assess the incidence of legislation, the effect of new ideologies on his trade outlook, the geographical changes which speed of transport have brought about, and a dozen other factors that affect the decisions he is called upon to make." One of the phrases frequently recurring in contemporary speech and writing is "The law of the jungle." The mere reiteration of this phrase would appear to indicate an acknowledgment that jungle law still determines the nature of many of our human relationships, and if the work of the Public Relations Committee does no more than awaken in the mind of the engineer a desire to take some part in the elimination of jungle law it has again achieved no small part of its purpose.

Scientific thought is reaching out into realms of new dimensions which may bring to man a better knowledge and a more noble conception of himself and the universe around and beyond him. Applied science, with the pressure of a child's finger, shapes and directs matter to man's needs, but in his human relationships he stands poised, tense for some catastrophic occurrence of his own creation. Nations bend their efforts to the power to destroy and burrow in the earth like frightened animals. Is it to be wondered that the men of healing, the men of science, and the engineers, are turning their minds to public relations, which after all is but a facet of that wider, vital issue—man's relationship to his fellow-man.

SOUTH MIDLAND CENTRE: CHAIRMAN'S ADDRESS

By H. FAULKNER, B.Sc.(Eng.), Member.*

(ABSTRACT *of Address delivered at* BIRMINGHAM, 12*th October*, 1938.)

For the purpose of my Address it is proposed to review the technical development of Post Office telecommunication services during the last few years. These services will be divided under headings of telegraphs, cables, and telephones, and I hope to be able to indicate to you in each case the trend of such development during recent years, problems in course of solution, and future possibilities. Mention will also be made of the electric light and power services which are dealt with by the Post Office Engineering Department.

TELEGRAPHS

Since 1931 the whole telegraph system of the Post Office has been completely revolutionized and the new system has been described before this Institution.† Previous to that time the bulk of the telegraph services were carried on on a direct-current basis, the particular system in use being the Wheatstone Machine Telegraph System, and for smaller quantities of traffic the Post Office Sounder System. In addition, for special purposes such systems as the Baudot telegraph, Hughes, etc., were also in use. Practically the whole of the telegraph service has now been placed on an alternating-current basis and the voice-frequency system of working has been adopted. This system involves the use of alternating currents at a number of different frequencies within the range of speech, applied simultaneously to the same circuit and separated at the distant end by suitably designed filter circuits. The standard system utilizes 18 such frequencies, and therefore one 4-wire telephone circuit can be used to accommodate 18 telegraph channels in each direction. The use of alternating currents in this way unifies the transmission requirements and does away with the necessity of segregating the telephone and the telegraph cables, and there is now one common trunk network for all services. Many of the old main underground telegraph cables have been balanced and loaded and are now used as part of the general scheme. Thus very considerable economies have been made in the cables used for purely telegraphic purposes. The system adopted for signalling is the teleprinter system, which employs a typewriter keyboard and types the message direct.

Private Wire Circuits.

It is well known that two circuits can, by the use of suitable transformers, be utilized to produce a third, "phantom," circuit. In a similar way two phantom circuits can be connected together in order to produce a super-phantom circuit. Owing to the electrical characteristics of the line, however, it is found that these super-phantom circuits are not suitable for telephone purposes. After considerable development work, however, it has been found possible to utilize them for telegraph purposes. They are known as by-product circuits, and many private-wire telegraph systems have been provided by this means. Private wires can, however, be of several categories, some, as above, being entirely telegraphic in nature, while others are alternatively telephone or telegraph. A "Telex" service making use of the telephone trunk network is also available by which a teleprinter can be connected to any similarly equipped position within the telephone system.

Switching

The problem of using automatic switching for public telegraph circuits has been very closely pursued of recent years, and experimental apparatus has been set up which has shown the practicability of such a system. By the use of this scheme intermediate offices will be cut out and, instead of having to receive and re-transmit messages a direct connection will be obtained to the office required, all or most of the re-transmission thus being avoided. Such a system will undoubtedly speed up the service considerably and will at the same time affect very considerable economies in operation.

Every teleprinter office will be connected to a switching centre by one or more circuits, depending on the size of the office. These circuits, which may be physical lines or voice-frequency channels, will work on a two-way basis and it will be possible to originate or receive calls on any circuit.

Since the teleprinter positions will not necessarily be permanently staffed, the teleprinters will be fitted with answer-back units to indicate the maturing of a call and the code of the office to which connection has been made.

Proposals are now under consideration for the conversion of the whole of the Birmingham zone to automatic teleprinter working, and the experience gained in this zone will enable the question of whether the full automatization of the Inland Telegraph Service will provide a satisfactory means of working the service to be decided.

CABLES

General development work is taking place in connection with underground cables in use on telephone and telegraph circuits. The principal development has been in the direction of the application of the high-frequency technique which has been developed in connection with radio circuits for land-line purposes. The adoption of this technique results in what is known as the "carrier current" system of working, known in

* Post Office Engineering Department.
† *Journal I.E.E.*, 1933, vol. 72, p. 189; and 1937, vol. 80, p. 237.

its early days as "wired wireless." A paper* recently read before The Institution described very fully the developments in this direction and the systems used both for the general carrier system and the co-axial cable system recently introduced, on which a number of circuits are worked at present from London to Birmingham. For this reason it is not proposed to go into the details of this development, but it seems to be clear that these systems will give a more economical and perhaps more flexible means of providing long-distance circuits than the older system which consists of repeatered circuits, a separate metallic connection being used for each circuit.

In addition to the land cables the co-axial type of cable has also been used for submarine purposes. These cables are concentric cables with paragutta insulation, and among others two such have recently been laid for the Post Office by Submarine Cables, Ltd., across the Irish Sea from the North Wales coast at Nevin to Howth in Eire. Paragutta is a new insulating material prepared by a special process from balata rubber and refined wax, and has the necessary qualities of strength and permanence, together with electrical qualities which make it specially suitable for submarine work. The method of working this type of cable is of course very similar to that employed in other carrier circuits. It is, however, impossible to provide the repeater stations at close intervals along the route as is the case with land-line circuits, and terminal repeaters have to be provided to give greater amplification than is normally necessary. The amplifiers used are of the negative feed-back type having an amplification of 67 db. It is proposed to work the "go" circuits on one cable and the "return" circuits on the other, the cables being separated by a distance sufficient to keep the cross-talk, which is greater at the lower frequencies owing to the reduced screening efficiency, within the required limits for satisfactory working. Owing to the greater amplification necessary, greater separations are required than is the case with land-line circuits. The two cables will provide 16 four-wire circuits between Nevin and Dublin, one of which will be utilized to provide 18 telegraph channels.

Future progress in carrier-wave transmission may be realized by the use of hyper-frequency wave-guides.† In this system electromagnetic waves are sent through "guides," which may consist of an insulator surrounded by a conductor or even of an insulator alone. A particular feature of some forms of this electrical propagation is that the attenuation decreases with frequency, a fact which may prove to have great significance in connection with the transmission of television over cables, and for use in the main telephone trunk network.

Local Cables

In laying-out local cables for telephone distribution purposes in an exchange area, means are adopted for providing a certain amount of flexibility. Although very careful surveys as to the number of prospective telephone users are made it is impossible to foretell exactly where telephones will be required. The main underground cables, i.e. cables serving an area having a growth greater than a specified rate, are laid on a basis of the forecast for the 8-year period, and plant forward of this point up to and including the distribution poles is planned on the basis of the forecast of the 20-year growth. At the point where the 8- and 20-year periods meet it is the usual practice to introduce what is known as an "auxiliary joint." The cables concerned may contain 150 or 200 pairs, and since this results in a comparatively large cable, and as the pairs forward from this point are greater in number owing to the longer planning period, it is the practice to provide a smaller joint in parallel with the main joint so that pairs may be changed over from one minor cable to the other as the actual growth requires. Thus if the growth at one particular point is greater than the forecast, whereas that at another point is less, the change-over of the wires back to the exchange can readily be made without opening the main joint. To avoid plumbing and un-plumbing such auxiliary joints a specially designed copper sleeve having a rubber gasket has been provided, and by this means any alterations necessary can very readily be made. It is also the practice to tee several pairs to 2 or more distribution points in order to give further flexibility and enable a more economical use of plant to be made without opening joints. It will be appreciated that, since a separate pair of wires back to the exchange has to be given to each telephone subscriber, the problems of distribution are very much more complicated than is the case with electric power distribution, where a simple tapping from the common main adequately meets the case so long as the average demand is properly estimated.

TELEPHONES

Transmission

Limits for various circuits.

It is the aim of the transmission engineer so to design his circuits that a good conversation can be given from any telephone in the country to any other telephone. It is therefore the practice to divide the country up, first of all, into zones. In each of these zones an exchange is selected to serve as the telephone zone centre. For example, Birmingham Trunk Exchange at Telephone House represents the Birmingham telephone zone centre. These zones are then divided into groups and similarly an exchange is chosen to act as the group centre. As an example, if we take the Birmingham zone we have group centres at Banbury, Birmingham, Burton-on-Trent, Cheltenham, Coventry, Derby, Evesham, Gloucester, Hereford, Kettering, Leamington, Newtown, Northampton, Rugby, Shrewsbury, and Wellington. Thus the majority of telephone communications from exchanges connected to these group centres would circulate first of all to their group centre, from group centre to zone centre, then to the zone centre of the wanted exchange, then to the group centre of the wanted exchange, and so to the exchange required. It should, however, be mentioned that within the group there are minor exchanges which have direct connection to the group centre, and also "dependent" exchanges

* A. S. Angwin and R. A. Mack: "Modern Systems of Multi-Channel Telephony on Cables," *Journal I.E.E.*, 1937, vol. 81, p. 573.
† *Bell System Technical Journal*, 1936, vol. 15, p. 284.

which have no direct connection to the group centre but are dependent on the minor exchange for completion of long-distance traffic.

Having organized the general routing of traffic in this way it is then necessary so to design the communicating lines that the transmission loss—which is measured in decibels—does not exceed certain limits between any two exchanges. Connections between the zone centres form the most important link in the chain, and it is the aim to provide all such circuits on a zero-loss basis. Each zone centre will thus be provided with zero-loss circuits to every other zone centre, and in this way communication over the greater part of the distance between any two exchanges is produced without any loss at all. This is, of course, made possible by the use of thermionic-valve amplifiers or repeaters, combined where necessary with "echo suppressors" and "stabilizers." From zone centre to group centre the loss allowable is 3 decibels, from group centre to group centre 3 decibels, from group centre to minor exchange 4·5 decibels, from group centre to dependent exchange via minor exchange 4·5 decibels, from group centre to minor exchange (multi-exchange area) 6·5 decibels, from minor exchange to minor exchange 12 decibels. Thus if we visualize a connection between two minor exchanges in different zones we might have losses as follows:—

Minor exchange to group centre	4·5 decibels
Group centre to zone centre	3 decibels
Zone centre to zone centre	0 decibels
Zone centre to group centre	3 decibels
Group centre to minor exchange	4·5 decibels

This gives an overall loss, neglecting switching losses at the exchanges, of 15 decibels. The realization of this aim is not yet complete but there is no doubt that before very long these conditions will be obtained between any two exchanges in the country. In addition to the design for the routing of trunk calls, it is also necessary to lay down limits for subscribers' connections. With the central-battery system the efficiency of the telephone depends largely on the loop resistance, which determines the current flowing through the subscriber's transmitter. Limits are therefore laid down for the maximum loop resistance for any subscriber's circuit, and this factor has to be borne in mind whenever local line plant is designed. It will be seen later that a modification in the design of exchange equipment has enabled greater resistance of subscribers' routes to be used in certain cases, with a consequent saving of copper.

With the means of amplification provided by thermionic valves comparatively small-gauge conductors can be used for the trunk and junction circuits, and the loss made good. Repeaters are used at intermediate points on long trunk circuits.

In the last year or so the use of "ballast" resistors in the transmission bridges in exchanges has been adopted as standard. The ballast resistor (or barretter) consists simply of a pair of tungsten filaments in an atmosphere of hydrogen and, as is well known, it has the property that its resistance increases as the current through it increases. The standard transmission bridge formerly used in automatic exchanges contained 2 relays of 200 ohms resistance each (which act both in a signalling capacity and as choke coils) in connection with a 50-volt battery. A loop of 450 ohms resistance to the subscriber was allowable under these conditions. With the insertion of the "resistor barretter" it is possible to reduce the resistance of these relays to 50 ohms, the inductance being restored to normal by the use of nickel-iron cores. In consequence it is possible to increase the allowable resistance of the subscriber's loop to 600 ohms without any deterioration in the quality of speech obtained either from distant subscribers or from those in the near vicinity of the exchange. It will be seen, therefore, that these modifications in exchange design will allow considerable savings in copper to be made.

The transmission limits mentioned above can also be provided on the carrier cables which have previously been mentioned, but in this case special repeaters which amplify uniformly over a wide band of frequencies need to be provided at much more frequent intervals than in the ordinary case.

On the long-distance circuits using radio links a technical operator is provided with means for controlling the volume of outgoing speech by the adjustment of a gain control, so that the transmitter is always fully loaded. Automatic means of performing this fnnction have now been developed and are being tried out in London. In addition to the long-distance radio circuits, additions to the inland network have recently been made by means of ultra-short-wave radio links. The first circuit of this type was brought into service on an experimental basis in 1932. Considerable advances have been made during the last few years, and this additional aid to telephone communications can be said to have taken its place on a commercial scale. Aerial arrays, of "Kooman's" or "Pine tree" type are usually employed for these communications. Power outputs vary from 1 watt up to 250 watts and the transmitters are crystal-controlled. The transmitters are exceedingly compact and take up little more room than an ordinary broadcast receiver. In the early days receivers of the super-regenerative type were employed, but a receiver of the super-heterodyne type having a crystal-controlled oscillator has been developed and is used as standard, with greatly improved results. Multi-channel working is now resorted to and arrangements have been made to provide 9 circuits with one transmitter and one aerial system. Plans are proceeding to provide a radio link of this type between the Isle of Man and Holyhead. It has been decided to install at the outset 6 transmitters capable of giving an output power of 100 watts each in order to avoid the necessity of replacement of low-powered transmitters when multiplex working is required on these links. The transmitters will be under-run initially. It is hoped that by the time the 12-channel line carrier system is ready for establishment on the circuits to the island that it will be possible for the radio equipment to accept the 12-channel line signals for direct transmission without the need for prior demodulation to audio frequency as is the case at present.

Apparatus has also been developed for radio-phonogram working for use between outlying islands in the north of Scotland and the mainland, and for this the same apparatus is used for transmitting and

receiving, suitable switching arrangements being provided. The apparatus has been called a "Transceiver." As the traffic to be handled on the radio-phonogram circuit is very small, provision is made for automatic calling in either direction. The equipment is switched on as a receiver by means of a time switch for about 1 minute every hour, so that, if the distant end wishes to call, the apparatus there is connected for transmission during this time. The switching-on of the transmitter causes the receiver output noise to be reduced by some 40 decibels by the action of the incoming carrier, and this change in noise level is utilized to energize the calling bell. The time switches are staggered by half an hour to allow for calling in each direction. Such circuits have been erected between Lewick and Skerray, Sandness and Foula, Sandness and Papa Stour, Hewna and Stroma, Soay and Elgol. These ultra-short-wave radio circuits are therefore fulfilling a long-felt want in the more sparsely inhabited parts of our country, by providing communication to places which were formerly out of touch with the rest of the country, normal cable communications being out of the question on economic grounds.

Developments have also taken place in recent years on the long-distance radio-telephone circuits. A transmitter has now been operating on traffic on the short-wave single-sideband system for nearly a year, the tests of the system having been carried out for a long time prior to its application to a traffic channel. A pilot carrier of strength 26 db. below the peak sideband level is used for synchronization and gain control. Early this year further equipment was added to the transmitter and receiver so that two channels can be provided for on the one radio system.

On the receiving side the future development of the "MUSA" ("Multiple unit steerable antenna") system recently described before this Institution* seems likely to make a marked advance in the fight against fading on short waves. In this system a number of rhombic antennae are separately led into the receiving building by means of co-axial cables connected through phase-shifters so that sharp directional effects can be obtained in the vertical plane. Incoming waves at several different angles are received separately and combined together in the audio stage. A monitoring receiver is also provided, associated with a cathode-ray tube in such a way that the angles at which the most effective rays are arriving can be observed.

It has been shown that during magnetic storms the waves are deflected from the great-circle path in the horizontal plane, and it seems likely that future developments will lie in the direction of making the directivity of receiving aerials variable in both horizontal and vertical planes.

Transmission testing

In order to ensure that the results aimed at—a uniformly satisfactory telephone service between any two points in the country—are in fact achieved, it is necessary to set up adequate means of testing, and very considerable strides have been made in this direction in recent years.

* *Journal I.E.E.*, 1938, vol. 83, p. 395.

The first link in the chain is the telephone transmitter, for it is at this point that speech vibrations are converted into corresponding electrical vibrations, and if this conversion is inefficient satisfactory service cannot be given. Special devices have therefore been designed for the direct testing of subscribers' telephone transmitters and their connections to the local exchange. They consist of a "noise generator" and a decibel meter. The former is a clockwork device which is wound up and positioned in front of the microphone of the subscriber's circuit to be tested. When released, small, hard steel balls strike a projection and produce a distinctive noise which covers the required range of speech frequencies, the instrument being carefully checked to deliver a particular volume of noise. The "decibel meter" is simply a moving-coil voltmeter associated with a copper-oxide rectifier with a reversed movement and calibrated directly in decibels.

The noise generators are carried by faultsmen and fitters, while the decibel meters are fitted on the test desk of the appropriate exchange. A check reading should be taken and recorded whenever a new instrument is fitted, and faultsmen should make a test when visiting a subscriber's premises on the occasion of a fault. There are, however, certain cases of non-attended exchanges where the tests cannot at present be applied.

For measurement of the transmission equivalents of trunks and junctions other apparatus has been evolved. On the long repeatered lines special apparatus is provided at the repeater stations, while portable apparatus utilizing a valve oscillator for sending and a valve voltmeter for measuring is available for measurements of losses on exchange apparatus, junctions, and through connections on which complaints of transmission have been received.

It will thus be seen that telephone communication is being engineered on a definite measurement basis, which is having a very marked effect on the quality of service given to the subscriber.

In addition to these checks on the volume of transmitted speech, attention is also being given to the improvement in the quality of speech. The cut-off frequency of the earlier cables was about 1800 cycles, whereas modern standards as exemplified by the International Consultative Committee for Telephony (C.C.I.F.) give an upper frequency limit of 3400 cycles. The newer instruments now being designed in this country give an even greater frequency range than this. It has been established that considerable improvement in intelligibility is obtained by transmitting the higher frequencies, but it will be realized that greater expense is involved, especially in the case of carrier-wave working.

Switching

(i) Local Services.

It is the policy of the Post Office to convert all local services to automatic working, and approximately 54 % of the work is now completed. The system to be used in any given case depends upon the circumstances. Medium-sized towns can often be served by a single exchange with a simple 3- or 4-figure numbering scheme, but the larger towns or groups of towns may need several exchanges and arrangements to be made so that

the dialling of an additional digit gives access to a direct junction to the particular exchange in the area required. In the case of very large cities, however, such as Birmingham, the provision of direct junctions from any one exchange to all the others would be prohibitive on economic grounds, and the "director" system overcomes this disability. The apparatus known as the "director" enables a call on any one exchange to be routed to the wanted exchange in the most economical manner. This may be direct, via other exchanges, or via a "tandem" exchange. The series of digits required for this routing will vary from exchange to exchange, although the digits dialled by the subscriber (the first three letters of the wanted exchange) will be the same. The "translation" of the dialled digits into the "routing" digits is carried out by the "director."

These systems are now well known and well established, and the full application of the automatic system to the countryside is now being tackled. Here different problems present themselves for consideration. The present programme envisages the dialling of all calls up to a maximum of 15 miles distance, i.e. up to a charge of 4d. It is, of course, necessary to cater for the payment for such calls, and the policy therefore involves a system of multi-metering, and apparatus has accordingly been designed for this purpose. The subscriber's meter is caused to operate once for a single-unit call, twice for a two-unit call, and so on to 4 times for a 15-mile call. In this system it is necessary for the subscriber to dial a code which may consist of 4 digits in addition to the digits of the required number, in order to connect his call to the required exchange. This code also supplies the necessary agent for the operation of the multi-metering device.

For very sparsely populated districts where the anticipated growth does not warrant the provision of a unit-type exchange, special apparatus known as a "country satellite" exchange has been designed and developed by the Post Office. The switching apparatus in this case is fitted in a sealed cast-iron box and is mounted on a telegraph pole. Ten subscribers can be provided with service in this way. Owing to the delicate nature of the relays, etc., and the bad effects which any tendency to corrosion would have on them, silica gel is placed inside the hermetically sealed box to absorb any moisture therein which would be condensed on the metal parts with changes in the atmospheric conditions. The silica gel is so treated that when saturated with moisture a change in colour takes place, when the necessary steps can be taken to dry it out or replace it. The experimental models of this system were installed some 4 or 5 years ago and have given very good service. A scheme based on the carrier-current system is also being tried out.

(ii) Trunks.

The problems involved in switching the longer-distance calls are now receiving attention. Signalling and dialling on the local network is carried out by means of direct current, but beyond a certain range difficulties are encountered owing to the high resistance of the lines, the presence of amplifiers and repeaters which will not pass direct currents, and the distortion which occurs on the dialling impulses owing to the characteristics of the line. Difficulties have, as a matter of fact, been encountered on the extended local network just described, and have been overcome by the design of mechanical regenerators and valve devices. The general problem on trunk lines is being solved by the use of alternating currents having frequencies within the audio range, which can of course be dealt with by the amplifiers and repeaters in the ordinary way. The difficulty to be overcome is that of possible false operation of the devices by the voice, which of course covers a range of frequencies, and some form of electrical discrimination has to be introduced. In the system which is being developed for use in the Post Office, two frequencies are used, viz. 600 and 750 cycles per sec., and it will be possible to provide calling and clearing signals, flashing signals enabling either operator to recall the other when working between two manual exchanges, or dialling facilities from a trunk exchange into a remote automatic exchange system, so rendering possible the extension of automatic switching to long-distance circuits.

ELECTRIC LIGHT AND POWER SERVICES

In addition to telecommunications the Post Office Engineering Department is responsible for the electric light and power services in all Post Office buildings, It may be of interest to mention that electric lamps are installed of a total wattage of more than 20 million, and that some 26 million units per annum are delivered from Post Office transformer stations alone. The maintenance of postal conveyors, stamp-cancelling machines, bag-cleaning machines, electric trucks, fans, and many other kinds of electrically driven appliances, is also undertaken.

Postal conveyors have improved the speed and efficiency with which mail can be handled, and it is perhaps interesting to mention that the parcel glacis at Mount Pleasant, which holds about 5 000 parcels, can be cleared, the primary sorting completed, and conveyed to the secondary sorting positions, in just over 10 minutes.

Future progress will probably be in the direction of electro-mechanical systems of sorting and facing letters.

In conclusion, I hope I have been able to indicate to you the wide range and variability of the problems which beset communication engineers. Many other aspects of the work, such as the improvements in design of instruments, apparatus and circuits in order to reduce fault incidence and improve service, the standardization of relays, selectors, etc., the design of new apparatus such as time-announcing apparatus and impulse regenerators, radio transmitters and receivers, etc., the study of problems of cable corrosion, electrolysis and creepage along ducts, the study of new methods of performing the various operations necessary in the construction of new lines, in improvements in the efficiency of doing the work, etc., are too many and varied to be dealt with in a single review, but I should like to finish by assuring my hearers that every effort is being made to give a cheap, reliable and, above all efficient, telephone service.

My acknowledgments are due to Sir George Lee, immediate Past-President of The Institution, and Engineer-in-Chief of the Post Office, under whose guidance this progress has been made.

MERSEY AND NORTH WALES (LIVERPOOL) CENTRE: CHAIRMAN'S ADDRESS

By E. L. MORLAND, Member.*

"UNIT BUILDING, AND ITS RESULTS"

(*Address delivered at* LIVERPOOL, *17th October*, 1938.)

I feel it can be accepted that the importance of unit building must be recognized during the coming years as a problem of the first magnitude.

The outlook of those engineers who possess a natural aptitude for directing the application of science to the practical every-day routine will be turned to the available fields, where their activities can be most usefully employed to obtain additional units.

It must be borne in mind that such constructive actions do not solely benefit the supply section of the electrical world, but cause far-reaching results which extend throughout industry. Such action, continually taking place, produces the most stimulating effects and is the cause of a large absorption of labour from the ranks of all classes of the unemployed.

A great deal is heard to-day of the widespread efforts which are in progress to increase the output of supply undertakings, but it must be realized that we cannot afford to become complacent, as a large amount of work still lies ahead to induce the public to increase their use of the advantages offered, at prices which will enable them to pay comfortably for the energy they use.

When examining the fields available for our efforts, the domestic one appears at once to be of primary importance, because of the increase of unit output which can be brought about by the consumer, who is taught to appreciate the conveniences and advantages to health which follow the adoption of electrical methods in the home.

To-day the first demand of a consumer is often for electric lighting and a radio receiver, which together use a comparatively small number of units. Later, however, consumers can be persuaded to use electrical energy for cooking, washing, water-heating, and other purposes, so that any alternative method is not required.

Builders of new estates have been aware for many years that without electric lighting they would be unable to sell their houses. The day is not far distant when the public will demand, in a similar manner, the installation of appliances to enable them to run their homes with the aid of electrical energy, and builders will vie with each other to provide them.

Suitable arrangements can be made whereby they install wiring for cookers and other appliances whilst the property is in course of erection, and a considerable saving is made in the cost of installation. There is then a minimum of inconvenience for the consumer who decides to install domestic appliances.

* Liverpool Corporation Electric Supply Department.

Many builders to-day are looking ahead and are installing inset panel heaters, with a consequent saving of the cost of a fireplace and chimney. In the absence of the chimney breast additional space becomes available, and it is only necessary to provide a ventilation flue. They have also considered fitting a refrigerator as a fixture in the kitchen wall.

The policy of equipping a show house on a new estate is welcomed by builders. It is immaterial whether the house is furnished or not, and if cookers, wash-boilers, radiators, and other appliances, are installed, the advice of an attendant often helps the consumer to decide at once to adopt the electrical method in his new home. Where the interest of the builder has been aroused, and with a saving on his outlay he has installed this method, no difficulty has been experienced in selling the houses to those who were prepared to use electricity as the sole means of providing the necessary facilities in a home.

Examples of private enterprise are known where in one district over 4 miles of roads have been built up and do not possess any other method for lighting the roads or providing energy to the 1 045 houses except electricity, as the builder refused to allow an alternative method to be provided on the estate.

In order to emphasize the increase of units which can be obtained in the electric home, it is of value to record an instance where 253 council houses occupy approximately 15 % of the area enclosed by a circle of $\frac{1}{4}$ mile radius, and are each provided with an average installation totalling 18 kW, comprising:—

Cooker	7 kW
Wash-boiler	3·5 kW
Two radiators	4 kW
Hot-water heater	2 kW
Cupboard heater	0·5 kW
Iron and lighting	1 kW

The maximum demand amounts to 1 000 kW and occurs on Sundays and Christmas Day; the total consumption for one year amounts to 1 009 059 units, an average of 3 988 per house. Dwellings of a similar type using energy for lighting average 200 units during the year, and it will be seen at once that the effect of using energy for all purposes is to increase the consumption almost 20 times.

The rateable-value charge of the two-part tariff, which is collected with the rent, amounts to 1s. 2d. per week,

and the units are ½d. each. The installation of the appliances was included in the equipment of the houses, and is maintained without additional charge.

The total amount collected for the year amounts to £2 869, an average of £11 6s. 10d. per house. The cost of the low-voltage network, laid underground, amounted to £9 10s. per house. It is not useful to give any costs for high-voltage mains as they depend entirely upon the distance of an estate from the power station or grid supply. In the example quoted, the cables, which pass through the estate, carry industrial load on week-days but are free for this Sunday load. In order still further to appreciate the immense possibilities of unit building in these domestic fields, it is interesting to consider 100 similar estates, totalling 25 300 houses. When the results previously given are multiplied by 100 the consumption becomes 100·9059 million units.

According to the figures given in the Ministry of Labour *Gazette*, plans for new buildings were passed by 146 of the principal local authorities during the three months April to June of this year. The total estimated cost for the quarter was £26 423 600, made up of the following amounts:—

Dwelling-houses	£17 297 800
Factories and workshops	£1 440 100
Shop and business premises	£1 945 500
Churches, schools and public buildings	£2 788 600
Other buildings	£2 951 600

The number of dwellings for which plans were approved was 35 551. The average cost per dwelling amounts to approximately £486. From the figures given in this tabulation the opportunities available for unit building can be further realized. The total value of the electrical installations and appliances to be fixed in these new houses, probably amounts to between 2 and 3 % of the average cost of the house, whereas the figure should be approximately 10 % to provide for a fairly complete range of appliances for everyday use. Based upon the recorded average for each house of 3 988 units per annum, the total consumption would amount to approximately 6·3% of the yearly increase of units sold in this country during 1936, as compared with that of the previous year.

Although central showrooms and careful advertising assist very materially in helping to produce the results mentioned, the most effective method is not to expect the prospective user of additional units always to travel to the central showrooms, but for suitable staff to seek out, on a definite routine plan, the households of which that showroom is a centre. In some areas it has been found that with the aid of printed propaganda 1 in 5 of the consumers use electric cookers. When, in addition, direct canvassing has been resorted to, 6 out of 7 use cookers; also 2 out of 3 have discarded the wash-boiler, provided free as part of the house equipment, and have hired an electric wash-boiler at a quarterly rental. In large areas additional (smaller) showrooms, at chosen community centres, can become the outposts of the undertaking. In built-up districts little difficulty should be experienced in finding the natural centre of the various communities which to-day form the population of an area. It is certain that considerably more attention and expenditure in developing the increase of units will be required in the future.

Another field for enterprise is that of building and industrial heating, although up to the present it has not been possible to progress very far. Where it has been practicable to install heat-storage apparatus the results have been satisfactory, and reasonable unit charges can be made when night storage of energy is possible. The levelling result upon the load curve is obviously of great value in helping to spread the standing charges of the undertaking, and loads of this description can usually be connected to the system without excessive distribution capital charges.

A possible load which requires close investigation is that of the railways, and it is to be hoped that economic and other considerations will eventually permit of at least the electrification of the local railways, together with the ensuing reduction of smoke and grime, the absence of which is so much desired by the public.

Street lighting produces a load which is continually increasing. It is quite helpful in adding to the units consumed, and possesses a fair load factor for a lighting load. Many engineers consider that street lighting has a definite publicity value, quite apart from the many advantages it offers. When examining the lighting of thoroughfares, those concerned with the prevention of the present toll of accidents during the night feel that the true test of good lighting is the measure of the uniform brightness of the roadscape, combined with the degree of visibility without glare.

At present these results are obtained either by the adoption of what is now described as cut-off lighting, or by suspending the source of light sufficiently high to be out of the normal direction of vision. When the source is visible in a glaring manner to the eye, the iris cannot partially close the pupil to the glare and simultaneously open to allow the weaker rays of light to strike the retina from objects beyond the source. It is this continual strain on the eye which is so trying to the motorist driving along roads where the source of light is visible. The public appear to require educating in this matter, for they still seem to prefer lamps which produce a glare instead of an evenly lighted roadscape.

Various methods are in use for switching-on street lighting; of these, centralized switching by a high-frequency impulse, which operates relays in the lamp columns, is found to be very satisfactory in operation. As many as 450 lamps can be operated in a district consisting of two areas, each of approximately ¼ mile radius, separately supplied from a substation in each area. The high-frequency impulse is transmitted from one substation along the neutral of the 4-wire distributors; it is therefore necessary to connect the neutrals, at the separation points in the underground network boxes in the two areas, by condensers which allow the impulse to pass. The relays are connected between the neutral and earth. The impulse method has possibilities worth considering for switching water heaters off the supply during the peak periods; this may enable higher load-ratings to be installed to obtain more rapid heating of the water.

A novel form of load is obtained by the use of soil-heating cable placed under the surface of a football pitch.

Experiments have been carried out with a loading of 5 watts per square foot in order to keep the ground soft during frost. It will be appreciated that the loss due to stoppage of play is a serious item. Where one length of cable was purposely omitted a stretch of frozen ground was left, whilst the remainder was soft and fit for play. Experiments are still being carried out in an endeavour to improve this scheme, which has already been highly praised by the officials of one noted football club.

In addition to the trial of soil-heating cables in glass-houses for the stimulation of plants which thrive upon hot beds, liquid-manure culture has been tried. The plants growing under glass obtain their nutriment from the manure within reach of their roots, and the temperature of the house is usually maintained at 70° F. by means of tubular heating or an electrically-heated water circulation.

Another recent horticultural development is the employment of a structure, also electrically heated and maintained at 70° F., to force the sprouting of grain laid upon trays and soaked in a solution approximating to the essentials in the earth. For example, maize will sprout a growth of 10 in. in 8 days. In a small hut sufficient can be produced daily to feed 30 cattle with 5 lb. per head, and this fodder acts as a stimulant when eaten with other food. The grain can be grown in winter and the method appears to possess great potentialities.

The rural portions of the country provide some very interesting problems before a supply can be made available. The individual unit consumption is usually large, although the total of an area is comparatively small. It is, however, essential to provide the amenities of life for those who are engaged in agricultural pursuits.

The problem of distribution in the rural area seems to divide naturally into two parts. In the first, it appears extremely unlikely that any urbanization of the countryside will, as far as can be judged, take place in the years ahead. In those areas the difficulty of balancing income and expenditure appears upon occasions to be insurmountable. In the second part, a change of country characteristics can be seen taking place on the fringe of most populous areas, and it is apparent that the rural district is rapidly about to become urban. The rural overhead distribution, which has then served its purpose as a pioneering effort, can be taken down and used elsewhere as the urban area extends its boundaries. The initial cost of the effort is then made up of the cost of labour, erecting, and removing, plus depreciation and loan charges on the capital value of the materials. The presence of a supply of electrical energy in these districts does encourage the development of that portion of a rural area adjacent to the urban area, and in many instances has resulted in the development of communities remote from any existing urban district.

It is becoming more fully realized that such self-supporting areas are very beneficial to the health of the population, and are more economic than the existing and often unwieldy areas which are still being increased by the spread of development. This method of providing for self-supporting populations will probably be used more extensively in the future, and will enable a distribution system to be laid down to meet well defined town-planning activities, with resultant economy.

As development progresses in these areas, the enterprise of an undertaking exercised to the fullest extent will result in a satisfactory increase in the use of units.

The provision of rapid and efficient service to the consumer is one of the duties of an undertaking of the utmost degree of importance in creating a feeling of reliability in the mind of the consumer. It should not be overlooked that the public judge an undertaking, not by the layout of the system, of which they possess little or no knowledge, but rather by the attention they receive from the undertaking. A day and night service is an excellent encouragement to the consumer to install the apparatus he should use to add to his consumption of units.

To retain the present rate of progress, and indeed add to the number of consumers and appliances connected daily to the supply, it is essential for the staff of an undertaking to collaborate with the electrical contractors in the closest possible manner. The maximum consumption of units can then be obtained, with the best results to the consumers, the undertaking, and the contractors. The appropriate associations have given, and still continue to give, the most valuable assistance in the work of unit building, and in the very important and vital work of raising and keeping at a high standard the workmanship carried out on a consumer's installation.

A large amount of research has already been carried out in connection with the standardization of plugs and many other appliances, and further rapid progress will be made if this most useful work is continually stimulated by those who have the necessity of standardization so much in mind.

Provision for the building-up of load, together with the view taken of future requirements, brought about the decision to build the Clarence Dock power station, and to develop it on a scale which would decide its future as the major generating station in the City of Liverpool and the surrounding area.

The existing power station at Lister Drive, situated some miles inland to the east of the River Mersey, occupies a position corresponding to the handle of a fan, of which the river forms the outer edge. The high-voltage system extended in a radial manner, with cables in duplicate and quadruplicate. The delivery of energy from Clarence Dock into the network was effected by the laying of 33-kV cables to join up with the terminal points of the existing system, at which step-down transformers were installed, and experience has shown the various types of 33-kV cables on the system to be satisfactory under full-load and heat-cycle conditions. At the same time the problem of the rupturing capacity of the existing switchgear had to be reviewed. The feed to the network taken from Clarence Dock had the effect of bringing the existing switchgear within zones where it became imperative to install switches of greater rupturing capacity.

In addition to providing for the distribution of energy from Clarence Dock power station, these arrangements have made it possible for the Lister Drive power station to run as a day-load and peak-load station, and the

whole design of the system enables the increase of load upon the undertaking to be dealt with economically.

The connection to the system of the Central Electricity Board is taken from the Clarence Dock power station at 33 kV. One feed passes through the Mersey Tunnel to Birkenhead, and the other is taken to the grid substation in Liverpool.

The supply to the Wirral Railway passes through the Mersey Railway Tunnel. It is metered in Liverpool and taken from the network at 11 kV.

The star points of transformers, together with cable sheaths and any metal parts requiring earthing, are connected direct to the water pipes of the city. Part of the supply is still provided by a 3-wire d.c. system; the middle wire is also earthed to the water pipes, by a standard resistance, at each converting substation. Electrolytic action on electric supply cable sheaths, gas mains, or water mains, is unknown, although the maximum traction load amounts to over 27 300 kW.

Unit building brings in its train the need for the provision of additional transforming points in a network, and occasionally some difficulty is experienced before a suitable site can be procured.

The compulsory powers available are very limited in their application, and at times considerable delay occurs before purchase or even purchase terms can be arranged, although it is found that landowners are usually very sympathetic to the desire of the undertaking to provide for future developments.

Where a brick building is erected to house transforming plant, a considerable saving in building costs can be obtained by eliminating such items as glazed wall tiling, tiled floors, and pits below ground-level. A sloping ramp from the substation floor to the requisite depth will admit the cables. Utility inside and aesthetic appearance outside need be the sole considerations.

When commencing the design of a standard a.c. network, distribution is often limited to a radius of $\frac{1}{4}$ mile from the substation, and practice has justified the policy. When loads of 1 000 kW are produced by houses occupying roughly 15 per cent of this area, it will be realized that sites should be purchased of ample size, in order to house additional plant as the load gradually increases. It will also be apparent that it is necessary to plan ahead to obtain sites where energy transmitted at grid voltages can be transformed for feeding into the high-voltage network.

The problem of voltage regulation on a system requires continual consideration as the building-up of load increases the total demand. Variations of voltage, which usually pass unnoticed on a gas-filled lamp, become of great importance where appliances containing resistors for heating purposes are connected to the supply.

The design of a network and its copper capacity should generally be such that constant voltage is provided at the consumer's terminals. It should be recognized, however, that exceptions within the Electricity Commissioners' limits of variation may be unavoidable in rural areas and in districts where the network cannot be completed owing to the chaotic way in which estates are sometimes developed.

Many large undertakings distribute their energy from the power station at 66 kV and 33 kV, and then transform down into networks at 11 kV and 6 kV, and later transformed down to the voltage of the local network. When dealing with the problem of voltage regulation it is usually essential to install on-load voltage regulators at the high-voltage terminal points. This arrangement effectively regulates the voltage on the sectional 11-kV and 6-kV networks. The problem remains of maintaining voltage over the local network between the two extreme conditions of load and no-load.

The addition of automatic tap-changing gear may add 100 % to the cost of an 11 kV/400-volt transformer —a capital cost which in a sense is non-earning and may be money unwisely expended. The actual capacity of the network is not increased; only the maintenance of voltage is affected. It may be judicious to consider adding to this money so that the actual capacity of the local network is increased. This can be effected by the provision of additional transforming points which reduce the length of the 400-volt distribution. The ideal design is such that the line between the transformer and the consumer is the shortest possible length, and practical policy should keep as close to this ideal as circumstances permit.

As load-building progresses these distances tend to shorten with the addition of transforming points. This addition of feeding points reduces the large sections of copper which otherwise it is necessary to place underground when dealing with load density of a high order, and increasing difficulty is experienced in finding accommodation for such cables.

When designing the layout of a distribution system it becomes clear that cables of ample capacity should be placed in roads or districts running in the direction of supply, and of just sufficient capacity to meet requirements in the road or district which is transverse to the direction of supply. This policy is applicable to both high- and low-voltage networks.

Considerable economy is effected in distribution costs by the use of hard-drawn copper cables insulated with tough rubber compound and then braided. These are supported in porcelain cleats fixed under the eaves of houses; many hundreds of miles have been erected, and the method has been approved by the Electricity Commissioners and the Minister of Transport. Compared with the cost of underground cable the saving is very considerable and has undoubtedly made it financially possible for supplies to be provided which could not be considered upon an underground basis. A valuable feature is the speed with which the lines can be erected. The cables cannot be considered as unsightly when in position, and wayleaves are freely granted by property-owners and owner-occupiers.

After the Great War the distribution systems of many undertakings were more or less loaded. Most of the undertakings distributing direct current decided to begin the change-over to standard-voltage alternating current. As this work is not complete it is useful to mention that a consumer's installation which does not comply with the I.E.E. Regulations for the Electrical Equipment of Buildings—usually embodied as one of the general conditions of supply—becomes a matter for which the consumer is responsible, when it is noted that the

Regulations are identical for either direct or alternating current at the voltages usually employed for supply.

Arrangements can readily be negotiated in connection with the change of d.c. appliances for those suitable for alternating current. A contribution from the consumer can be agreed upon, representing a percentage of the cost of replacing appliances, based upon the depreciation of the d.c. appliances which have been in use.

Mention of the Great War recalls the precautions which have unfortunately become necessary in connection with the possibilities of damage by air raids. It is reassuring to realize that, owing to interruptions of supply which occurred from time to time in the earlier days of the undertakings, it has become general practice to duplicate most supplies. This duplication, usually from separate supply points and along different routes, would be of great value in the event of damage during air raids.

Of all the public services provided underground, electrical undertakings are in the fortunate position that if damage occurs on a network that portion will be automatically disconnected from the supply; the organization of an undertaking can then be directed to repair the damage.

With regard to the scales of charges for the use of electrical energy, criticism is often levelled at undertakings because of the varying tariffs in use, and it is suggested that they might be framed upon some standard rate and so simplified.

In this connection it must be remembered that electrical energy cannot be economically stored; therefore the problems of load factor and peak loads are fundamental and must be continually faced. It is immediately realized that different classes of load must possess characteristic load factors, and be clear or otherwise of the peak loads of the undertaking. It is therefore apparent why different tariffs are framed for various forms of load. The uses to which electrical energy is applied are continually widening in scope and it occasionally becomes necessary to institute new tariffs, which are expected to encourage a particular use of electrical energy at a price enabling the consumer to buy, and the undertaking to make a reasonable profit. The success of an undertaking largely depends upon the framing of suitable tariffs.

Industrial loads, for instance, almost invariably overlap the peaks of the daily load, and add their quota to the maximum demand of the system. A suitable inducement can be offered to power users by reduction of the maximum-demand charge, so that by careful discrimination on their part the plant which they find unessential to run at peak times can be shut down, with a consequent saving to themselves and to the undertaking.

I venture to refer to the contentious aspect of tariffs in order to ask a question concerning the future. How is the two-part tariff for houses to be dealt with? Is the demand charge or the unit charge to be lowered, or shall we reach the Utopian ideal of a demand charge or electricity rate without a meter? It should be remembered that the public are becoming electrically-minded more rapidly than is always appreciated. We are all engaged in creating an intense demand for the provision of cheap and abundant electricity which the public so greatly desire.

The present-day undertakings which unit building has helped to produce are very rightly a matter for pride upon the part of engineers, who in many ways give their best to the industry, and the provision of additional professional assistance is one in which the universities and technical schools are filling a highly important educational role. It is pleasing to realize how the universities are to-day directing part of their training to produce engineers who, in addition to possessing academical qualities, are also able to apply their knowledge, with initiative and judgment, to the every-day problems of the profession for which they have been trained.

Access by students and young engineers to the accumulation of experience gained since the earliest days of electrical supply is rapidly producing a body of men who will in the future be able to keep the undertakings in a high state of efficiency, so as to be of immense potential value to the population of this country.

To-day a high degree of engineering skill is directed, with very noticeable results, to the continual improvement of apparatus used in the system of an undertaking. It is expected that equal attention and research will continue to be given to the design and manufacture of materials and appliances used in connection with the requirements of a consumer, in order to obtain a still greater measure of reliability and efficiency.

I have endeavoured to draw attention to the supreme importance of unit building, together with its results, and I should like to remind engineers, who in the past have had such faith in the electric supply industry and its allied trades, that it still remains for us to continue our efforts to progress along the path of success, in the full knowledge that we are providing an essential service for the benefit of our fellow men.

NORTH-WESTERN CENTRE: CHAIRMAN'S ADDRESS

By W. FENNELL, Member.*

(ABSTRACT *of Address delivered at* MANCHESTER, *18th October*, 1938.)

The address of my immediate predecessor was an important contribution to the literature of The Institution, and an inspiration to all electrical engineers. I should like to supplement it with a very short appeal to you to utilize the increased status, not only in the professions but in relation to citizenship, accorded to members of our profession due to its growing importance. We have, in fact, entered a stage in our development which demands of us not only high technical ability, but a knowledge of the world which can only be gained by mixing with it. The way is now open for us to increase greatly our influence for good by making use of the many openings which now exist to engage in non-technical activities.

THE INSTITUTION

We are all proud of The Institution and the position it has attained amongst the scientific societies, but few of us have read our Charter and Bye-Laws more than once, and most of us take it all for granted. There are at the present time two matters relating to Rules or practice which may be considered.

Transfer of Graduates to Associate Membership

This matter has been the subject of many letters in the technical Press and may be referred to in The Institution itself because it affects the vital interests of those young men who are entering the profession.

At the moment some Graduates are involved in a vicious circle. They cannot become Associate Members until they have had at least 2 years' experience in that type of responsible position in electrical engineering from which they are excluded by the advertising employer until they are already Associate Members. This almost closes the way to advancement of clever young engineers without influence enough to obtain non-advertised responsible positions.

It must be noted that the difficulty is not primarily caused by The Institution or its Bye-Laws, but by the public lack of understanding of the fact that a Graduate is equal to an Associate Member as to technical qualifications, and that the only difference is one of responsible experience in electrical engineering.

One unfortunate, and I think undesirable, result is the appreciable number of resignations of Graduates, creating a growing body of technically-qualified electrical engineers outside The Institution. In my opinion the public will not change its attitude, and it is hoped that in some way the difficulty may be overcome.

The dictionary definition of the world "responsible" does not appear to be as formidable as its usual interpretation. It is "accountable—answerable." Every employed person is responsible, i.e. answerable to his employer for the way in which he carries out the work entrusted to him, and this literal or dictionary interpretation of the Bye-Law would clear the difficulty.

The sequence of transfer would then be as follows: Studentship; (Examination)—Graduateship; (2–5 years' practice in a position requiring a reasonable use of his technical qualifications)—Associate Membership; (5–7 years' successful practice in a leading position)—full Membership.

A secondary and, I think, desirable effect of the change would be to stimulate transfer of senior Associate Members to full Membership; as membership of that class would then become the recognized qualification for the more responsible positions. The change in interpretation would, perforce, lower the standard of transfer to Associate Membership so far as "responsible experience" is concerned, but not as to technical ability.

It is clearly a matter for the Council to decide, but it is hoped that this explanation of the surrounding conditions may help Graduates to appreciate the possibilities and also the difficulties.

Election to Council

The practice of the Council to nominate candidates for all vacancies may have been necessary in the early days, when the numbers were small. If the Council's list could be issued with one place vacant the prevalent feeling that "outside" nomination is allied to gate-crashing would be removed. This feature has been discussed verbally so often, and so widely, that it may properly be referred to in a chairman's address.

Centres

The advantages of our North-Western Centre are generally appreciated. In addition to the facilities which the meetings provide for the discussion of papers, the Centre provides an opportunity for local electrical engineers to get to know each other, to exchange views and, I believe, to assist mutually. The success of the Centres has been such that to-day one can scarcely imagine the conditions which existed before they were instituted.

In this connection I wish to bring before you a matter which has been of considerable interest to me personally.

Sections

The latest feature of the organization of The Institution, that of Technical Sections, has been in operation for several years.

One serious disadvantage to provincial members is that

* Mid-Cheshire Electricity Supply Company, Ltd.

the Sections are not yet linked with the Centres, although this is provided for in the Bye-Laws. All Section meetings are, therefore, held in London and they are of great use to those living in the Home Counties, but there is a small, or negligible, attendance of "provincials," almost limited to those who happen to have other business in London on the day of the meeting. In fact the unsatisfactory situation which existed for "provincials" in relation to the general meetings prior to the inauguration of Centres is repeated in relation to Sections, with the additional disadvantage that the technical Press does not often give prominence to Section papers, and usually ignores or gives a very brief abstract of discussions compared with those relating to papers read at the Ordinary Meetings. Most members of Sections, therefore, do not see either the papers or the discussions until they are published in the *Journal*, some months later.

The obvious cure in this case is the formation of branch Sections at Local Centres. There must be a substantial local demand before effective action can be taken. This matter is therefore in the hands of Section members resident in each Centre.

Wiring Regulations

The industry requires reasonable safety and convenience for the consumer, at the lowest possible cost, if only because high cost means few connections. While it must be reasonably safe, easy, and cheap, for the ordinary domestic consumer to use electricity, it must also be rendered difficult for contractors and others to carry out dangerous wiring.

This matter may be considered from several points of view, but the one which should be mentioned is that of the average consumer, whose interests are paramount. As there must be rules he usually desires two qualities in them: the first is brevity and simplicity, so that he can judge for himself whether they are being carried out in important matters, since not one consumer in 1 000 has a consulting engineer; the second is that the rules shall be drawn to provide safety, while keeping the price low. Neither of these presumed consumers' requirements is fully catered for in the I.E.E. Wiring Regulations, and it may be that there is no practicable way of doing so. The Regulations as drawn are also well above the heads of wiremen and foremen, who, in general, leave elementary schools at 14 to 16 years of age. Again, it may be that Regulations cannot be drawn down to the wireman's level, but one wonders whether this very desirable quality has been kept in view in choosing the actual words used. The Regulations are obviously drawn by experts for experts.

One difficulty is obviously that of scope. The Committee has produced one set of Regulations, which will cover all classes of premises and every kind of consuming device, in such a way that the wiring contractor has no option, if he follows the Regulations, but to produce not merely a safe but a nearly perfect installation.

While one cannot withhold admiration for the Regulations as an all-embracing code and a substitute for long specifications for important contracts, one wonders whether it is really necessary or advisable to spread the impression abroad that a domestic or shop-lighting installation with a few plugs, a wireless set, and a radiator or two, is so potentially dangerous that it needs so many precautions.

Another reason for the inordinate length of the Regulations is that they go far beyond matters affecting safety. For instance, they have been for several years a vehicle for the compulsory introduction of the British Standard Specifications for every item for which they are prepared. While this is outside the scope of regulations to ensure safety, and is not objected to in non-contentious matters, it contributes to bulk and complexity. There is, however, an acute controversy at the present time arising out of standardization in relation to the flat-pin plug, which is excluded by the Regulations because the relative British Standard Specification assumed that pins will always be cylindrical, and was prepared on that basis. It is urged widely that the flat-pin plug has so many advantages that the assumption was in error, and that a British Standard Specification should be prepared for flat pins.

There is much to be said on both sides. We, or the B.S.I. Committee, are in fact up against the ever present problem of standardization versus invention and improvement. In this example the relative evils of excluding what many believe to be the best plug and of allowing yet another type of plug contact will no doubt be carefully balanced before a final decision is made.

There is, however, a course which if adopted would reduce the number of standards for plugs. This would be to de-standardize all reversible, i.e. non-polarized, wall plugs, since they expose the user to serious danger wherever single-pole switches are in use on apparatus connected to a plug.

A potential danger which, in my opinion, is greater than any to be met to-day in fixed wiring is that of the indiscriminate sale by stores at bargain prices of electrical accessories and flexible cords, some of which infringe not merely the British Standard Specifications and the I.E.E. Regulations, but also the elementary principles underlying electrical construction. Such apparatus as bowl fires, toasters, irons, and vacuum cleaners with common flexible cords and flimsy connectors, are being scattered broadcast. The serious fault in many of them is that they are made according to designs which are tolerable, and even good enough, for 110 volts, as used in many other countries, but they are wound or sold for 200–250 volts. There appears to be no way by which this can be brought to an end, except by the establishment of a "Proving House," issuing a seal backed by an Act of Parliament. Even then the second-hand market would continue for years. Fortunately, the number of casualties due to these low cost accessories is very small. While I support strongly the idea of a "Proving House," and think that it would be for the benefit of the public, it will be objected to as coming under the description of "grandmotherly legislation" unless the scope of the Proving House is restricted closely to safety only of design and construction of actual accessories.

I can see no signs that there is any substantial public demand for more stringent wiring rules, for registration of contractors or workmen, or for the banishment of cheap electrical accessories from the stores, any more than there is for similar censorship of gas accessories and gas fitters. If there is one thing the public really likes, it is to buy a

bowl fire for 5s., unpack it with pride, and plug it in, or even wedge the wires into the socket with matches. Fortunately very few casualties result, which proves that nearly all plug positions where these stores bargains are used are "earth free." Amateur wireless "fans" also like to buy cheap wire and accessories of unknown lineage, and carry out minor extensions. Unfortunately, this cannot be prevented by the existing non-statutory Wiring Regulations, or by registration of contractors.

It must be borne in mind that so long as the I.E.E. Regulations go beyond the minimum requirements for safety, the Commissioners cannot very well embody them in their Regulations. There is, therefore, an imperative need for a short and simple supplement dealing with the minimum requirements for safety in the home and in business premises (omitting all the many items which deal with special or unusual uses, standardization, good practice, labels, warnings as to maintenance, etc.), with a view to their acceptance by the Commissioners for inclusion in their Regulations.

ELECTRICAL RESEARCH

I should like to pay a tribute to the work of the British Electrical and Allied Industries Research Association, which is very closely allied with us. It is an institution of which we used to dream—a place where highly qualified engineers could investigate those problems which were delaying progress, freed from the limitations imposed upon research by manufacturers who could not afford either time or money for their staffs to deal with matters which were not of immediate urgency. Moreover, there was waste, even in urgent matters, because two or three manufacturers were covering the same ground at the same time, none of them doing it under very favourable conditions.

COST OF APPARATUS

Electricity has so far made its way in the homes of the people by virtue of the superior amenities it provides, notwithstanding the relatively high cost of equipment, compared with its rivals.

The majority of the larger and wealthier domestic consumers have now been supplied. We are now in a zone where new consumers in towns have on the average 5 or 6 points only, and have to be won over from "other forms of light and heat." Assisted wiring (meaning gradual payment, hire-purchase or hire) softens or lengthens the blow, it is true, but does not decrease the cost of installation. The basis is still £1 a light, or more, as it was in 1900, but it is now plus interest and collection costs on the outstanding balances.

What can be done is to reduce the prime cost of cable and accessories by constant research with that object in view, and to reduce the labour involved in wiring, by improvements in terminals, boxes, and fixing. In my opinion a reduction of 25 % can be made in the cost of domestic installations with no increase in risk, and it must be done if we are to maintain our high rate of development.

I also suggest a reduction of overhead costs by overhauling sales organizations. Some articles cost more to sell than they do to make. The supply section has been chided because it has relied more upon the recommendations of satisfied consumers obtained by service, than upon high-pressure salesmanship and costly Press advertising programmes. Its publicity, including the work of the E.D.A., costs less than 1 % of its receipts. While I think this may be increased to, say, 2 % with advantage, I am also of opinion that it should not cost, as it does at present with the larger consuming devices, say 20 % to 50 % of the retail price of an article to persuade the consumer to buy it.

[Mr. Fennell here indicated several directions in which installation costs could be reduced with advantage, and pointed out the palpably high prices for the larger consuming devices.]

When one considers the smaller accessories, lamps, lampholders, adaptors, plugs, etc., it appears that the prime cost is low, but distribution costs are too high. The public is therefore rapidly changing over from the electric shop to the chain stores, to its great financial benefit. This change-over is a sign that electricity supply has really reached the poor or near poor, who cannot or will not pay the heavy "on costs" inevitable through the ordinary sales channels which the chain stores have short-circuited. The chain-store purchasing prices could no doubt be obtainable by contractors through bulk-buying schemes. Here is a promising field for the enterprise of the Electrical Contractors Association, because it will help the contractor to keep his retail counter trade and result in a more judicious selection and distribution of apparatus.

STANDARDIZATION OF TARIFFS

There has been no substantial progress during the last 10 years in the direction of a standard two-part domestic tariff applicable to all undertakings. This elementary item of standardization is most elusive. The position is somewhat as under: Any individual undertaking, however large, covering an area however diverse in character, is able to have one standard basis for the fixed charge, but if one takes two adjoining areas, almost similar, one will often find that each of the two engineers will be able to justify, for example, the rateable-value basis for one, and the floor-area basis for the other. Look at it in another way. Take areas at random and you will find no law governing the choice of the fixed charge basis—except perhaps a tendency to adopt the floor area, or number of rooms in the rural areas, and the rateable-value system for local-authority-owned undertakings.

I am sure that in the long run we shall adopt a graded system based upon the number of rooms, rather than the floor area, but if it is to be done soon compulsion will be necessary.

I have no doubt that whatever basis the Commissioners choose can be applied throughout the country and brought into use in six months. It would be necessary for the Commissioners to issue a direction as to system, with the instruction that the charges are to be so graded as to produce on the average the existing revenue on whatever different system is in use.

If the new basis is the most equitable, as it would be to qualify for selection by the Commissioners, this is a satisfactory answer to complaints. Since no change in apparatus is required, no capital outlay would be involved.

Comparison between tariffs in different areas would be easier. Also, one of the more or less justified causes of complaint against the industry as a whole would be removed. That alone would be worth while, and I am in favour of prompt action, as I was two years ago, when I suggested it in the London discussion of two papers on "Tariffs."*

SYSTEMS OF SUPPLY

This is a much more serious matter. Periodicity has already been dealt with, so far as it was required to facilitate grid operation, on a basis which shared the cost between the Government, as a relief for unemployment, and the distributor. It was reasonable that the non-standard undertakings should not be penalized, and there is little complaint at the burden of almost 1 % of the revenue from sales of electricity which will continue at a diminishing rate for say 20 years.

Proposals for compulsory change from direct to alternating current need careful consideration. The total number of undertakings is about 624. In the year ended December, 1936, or March, 1937, there were 267 undertakings supplying both alternating and direct current, and 46 supplying direct current only. The reason for the relatively large number supplying both systems is that in areas with a well developed central town it is difficult to justify the very large expenditure involved in a complete change. There is no disadvantage to the existing consumers, either business or industrial, in continuing to use direct current. This in my view is a case, similar to that of frequency, where it is not fair to penalize the undertaking and/or its consumers merely to secure uniformity. All would agree that, given an indemnity, the change is a desirable one.

STANDARDIZATION OF VOLTAGE

The standard voltage is 230/400. In 1936–37 there were 444 out of the 624 undertakings providing 230 volts for the whole or part of their areas. The statistics for the other voltages are confusing but are not material for my remarks. Broadley speaking, there are three widely differing sets of circumstances:—

Case (*a*) *Where a small increase will suffice, i.e. from* 220 *V up to* 230 *V*. This can be carried out at almost no net cost. The owners will gain about $9\frac{1}{2}$ % in mains capacity, while almost no consumer will be adversely affected. The standard notice, drawn up by the Commissioners, is discouraging to those undertakers who contemplate a change, because the wording encourages a spate of purely money-making claims for new lamps, etc., for old, when in fact the consumers would hardly know the change had been made if they were not told. However, an increase of 10 volts would standardize a substantial number of undertakings, and a little assistance from the Commissioners in the way of preparing a non-standard notice for this special case would bring about a prompt change.

Case (*b*) *Where a moderate increase is required, i.e. from* 210 *V up to* 230 *V.* Taking a 210-volt undertaking, the increased pressure would provide an increased distributor capacity of 20 %, but every consumer's lamps and most other apparatus, would either have to be changed or altered at heavy cost. On the balance there would be a substantial loss.

Case (*c*) *Where a considerable increase is required, i.e. from* 200 *V up to* 230 *V*. Curiously, although the change is greater, the increased distribution capacity is $32\frac{1}{2}$ %, which in many cases would balance the cost of change over.

Case (*d*) *Where a reduction is required, i.e. from* 250 *or* 240 *V to* 230 *V*. This includes all cases where reductions are necessary. Here there is a necessity to change or alter almost all consuming devices at heavy cost, and there is a loss of mains capacity ($15\frac{1}{2}$ % in the case of 250 V).

As none of the undertakings is to blame for having failed to predict the future standard when they commenced operations many years ago with voltages sanctioned by the Board of Trade, there is a strong case for an indemnity in all cases except (*a*), which only needs a special form.

I am sure that standardization is worth to the community the amount it would cost to carry it out equitably. It is obvious that the method adopted in the case of frequency could be applied, viz. to spread the net cost, after making equitable allowances as indicated, on a basis of revenue for sales of electricity.

There is one point which may be made: reorganization of areas will not automatically bring standardization. It would still have to be bought and paid for by the community. It would cost more later than it would now, because of the new consumers who would be connected in the substantial time which must elapse before a new body could get to work on a detail such as this.

THE REORGANIZATION OF ELECTRICITY SUPPLY

Our friends in the manufacturing and installation sections will agree that something like 90 % of their home business, excluding wireless, is derived from progress in public electricity supply. It is, therefore, important for the whole industry that we should push forward with unabated vigour. The electricity supply industry, however, is passing through a time of uncertainty as to its future orientation.

Politicians have so long been busy upon the discouraging task of reorganizing sick industries—cotton, coal, agriculture—that the brilliant idea has occurred to all the three parties that the Government associated with a reorganization of the already most progressive of the public utilities will almost certainly obtain public credit for the rapid upward progress of electricity supply. Unfortunately, times are abnormal, and a slowing-up of programmes of extensions has already resulted from the uncertainty produced by the long pause following the Electricity Distribution Committee's Report (McGowan), and the subsequent Outline of Proposals known as the "White Paper."

The scheme proposed by the McGowan Committee was to appoint temporary District Commissioners with powers to hold inquiries and to recommend mergers, with an emphasis on the conjunction of the terms large and efficient as if they were synonymous. Thus the large undertakings and especially the power companies were to absorb the small undertakings to form about 120 "Groups" in a manner and on a scale to be decided by these special "judges" on circuit. The decisions

* *Journal I.E.E.*, 1936, vol. 79, pp. 505 and 510.

were to be subject to approval of the Commissioners and of Parliament in each case, provided always that where only one undertaking selling fewer units than 10 millions in 1934 was concerned in a proposal, Parliament should not be troubled.

This reference to the small undertaking has raised protests from lovers of even-handed justice for large and small, and has precipitated what may fairly be termed a revolt of the small municipalities concerned. They formed a special Association, and, although the Outline of Proposals (White Paper) omitted the "10 million limit" and the District Commissioners, the Committee is still engaged in so organizing the members that they will be able to influence Parliament effectively against alienation of any municipally-owned undertaking. It is thought that they can bring some 100 or more M.P.s into the field to defend the rights of the small municipalities.

It would appear therefore that it is no longer possible to consider amalgamations merely upon a basis of engineering and economics. Any detailed proposals must now take into account the powerful objection of municipalities to part with their undertakings even where it can be shown to be advisable on economic grounds. It may be mentioned that the McGowan Report and the White Paper both visualized the termination of all power and other company franchises and also all Group Distribution Authority operation within 50 years, merging them into still larger units by the formation of Regional or Public Distribution (District) Boards, having an unlimited franchise. This ultimate structure does not attract large municipalities because, although they are immune in the immediate future, their undertakings would be absorbed ultimately by the Boards, whose members would be nominated by the Minister of Transport so that local influence would be destroyed. Thirty of these Boards were indicated as the eventual number of Distribution District Undertakings, say an average of three to each grid area.

A most important point which arises in relation to any large-scale reorientation of distribution, which does not also absorb the Central Electricity Board, is its effect upon that Board.

The Regional grid area, with its complex financial structure, based upon the existence of numerous undertakings as consumers, will then have in fact only a few customers, each consisting of merged undertakings buying from the grid at several points. The logical policy of the new distribution units or Boards would be to reduce the number of grid connection points to secure the benefit of diversity. This concentration would rob the Central Electricity Board of its tariff consumers, who now produce much of its net revenue necessary to meet its operating expenses and capital charges, since each of the Groups will have a selected station and will usually buy on lower Section 13 terms, viz. the cost at which they could generate if there were no grid. This change-over from tariff to Section 13 buying would threaten the financial stability of the C.E.B.

It was proposed, in the "White Paper" to counter this eventuality by providing that payments to the Central Electricity Board by distributors should be maintained at the figure at which they would have been if there had had been no mergers. This artificial barrier to distribution economy might save the Central Electricity Board from disaster, but it would remove from the merger idea its principal hope of financial success, which should be a reduced cost of its raw material—power—by large-scale generation or purchase.

The proposed saving clause has in fact revealed the principal technical and financial objection to any scheme of large area organization of distribution at this late date, since a substantial portion of the Central Board's capital has been spent to provide for each undertaking, both large and small, a cheap source of supply in the area. This has removed the financial handicap previously experienced by the small-area undertaking.

The McGowan Committee's Report did not indicate any direct saving in cost of distribution as a result of the proposed merging of existing undertakings, so that the case for mergers relies almost entirely upon the secondary advantages claimed, such as improved publicity, standardization and reduced cost of future extensions by large-scale planning. The last named item is doubtful, because each sub-area would be supplied as now from its grid connection. The question arises—Is a revolution in the industry necessary now that the grid is in operation, in order to secure these desirable features?

I would refer you to a paper which I read before The Institution in November, 1935, for a summary of my proposals for a suggested Electricity Supply Act.* The summary included consolidation of the existing Acts, and 13 headings for suggested amendments, to remove most of the disadvantages under which we labour. I embodied such of them as related to reorganization of areas in my evidence before the Electricity Distribution Committee in December, 1935, which was shortly as under:—

(1) The available statistics, circulated at the opening of the Committee's inquiry, as the basis of its investigations relate to pre-grid operation only. The small undertaking under the grid system is in a much more favourable position to provide cheap electricity than shown by these statistics.

(2) The large undertakings were not notable for low domestic charges. Figures were given to support this. With one grid tapping point in its limited area, the small undertaking has the advantage of avoiding extra-high-pressure transmission which, together with the cost of administration over long distances, handicaps the large one. This view was supported by citing the fact that the units sold per £1 of capital expenditure has been stationary or rising, notwithstanding an improved load factor during the recent period when areas had been growing larger.†

(3) The existing rapid increase in connections might easily be retarded and not accelerated by the substitution of large organizations and bureaucratic control for the small organizations having local and personal understanding of local differences, and power to meet them.

(4) I suggested that the Commissioners should be given powers to approve, not as at present, only the maximum flat-rate tariffs, now rapidly falling into disuse, but the actual domestic tariffs, both as to form and amount for each undertaking, after considering local conditions.

* *Journal I.E.E.*, 1935, vol. 77, p. 763.
† *Ibid.*, 1933, vol. 73, p. 97.

(5) I proposed, in order to promote standardization of tariffs and systems, and to remedy the admitted backwardness of some undertakings as to hiring, hire-purchase, and publicity, that the Commissioners should act with the advice of area Joint Electricity (Advisory) Distribution Authorities, which could be formed under the 1919 and 1926 Acts and be similar in constitution to the South-East Lancashire Advisory Board, which operated for generation, and to some extent for distribution, with marked success in this area, prior to grid operation. Such advisory authorities would be formed on a group basis of representation to secure that all undertakings were well represented, but that none should predominate. There would also be representatives of local authorities not owning undertakings, to represent consumers. A corresponding Engineer's Committee should be formed as in South-East Lancashire. The Board's principal duty would be to advise, encourage, and urge owners of undertakings to bring about improvements in, and standardization of, systems, tariffs, hiring, and publicity, and where necessary to report to the Commissioners cases where, in their opinion, an undertaking was financially too weak, or unreasonably neglected or declined to implement the advice given. The Commissioners would be given power, after holding an inquiry, to deal with such cases if necessary by report to Parliament through the Minister of Transport, with a recommendation in extreme cases that the undertaking be transferred by purchase on a "then value" basis, to the local authority or a neighbouring undertaking.

I intimated that no reasonable engineer and manager would resist the conclusions come to by his fellow members of the Engineering Committee having full knowledge of local conditions, and that his "undertaker" would rarely force the issue to a hearing by the Commissioners. The result would be a prompt quickening of the backward undertakings, and as rapid a move to standardization of voltages, systems, and tariffs, as would be possible without serious dislocation.

I suggested that by adopting this proposal the advantages claimed by the advocates of large distribution areas could be obtained without the disadvantages such as creation of hostility of the dispossessed local authorities to the new authority and the loss of elasticity inseparable from big business.

(6) I suggested that in no case should a company undertaking extending into several local-authority areas, be purchasable piecemeal as at present, by several separate local authorities and split up, but only by a Joint Board formed from the local authorities concerned.

Incidentally, I informed the Committee verbally that with regard to the then rumoured scheme of compulsory mergers it was impracticable to propose wholesale alienation of small local-authority undertakings since they could influence so many members of Parliament. In this matter at least I was a good prophet, since this feature has caused bitter opposition.

It is also clear that no rational scheme of wholesale area reorganization can be produced without this revolutionary feature, which may easily produce something very like war in our industry, and a serious set-back to the remarkable progress in connections which has been a feature of the least few years.

I consider, therefore, that the present is a suitable time to publish any alternative and peaceful proposals calculated to remove the existing handicaps (chiefly the result of past legislation to secure standard systems) and to deal with backward undertakings.

I recommend proposal No. (5) above to your consideration, as a possible solution of the problem.

NORTH-EASTERN CENTRE: CHAIRMAN'S ADDRESS

By F. A. ORCHARD, Member.*

"THE HISTORY OF A PIONEER UNDERTAKING"

(ABSTRACT *of Address delivered at* NEWCASTLE, *24th October*, 1938.)

INTRODUCTION

As it was my privilege some 6 years ago to become an official of a small undertaking with a comparatively greater history, I felt it would not be without interest to the members if I were to give an account of what has been done in the past and of the efforts which have been made in their own district.

It is because I have been impressed with this history that I feel this impression should be disseminated, particularly to this Centre, where local history has been so rich in interesting development.

ORIGIN

In these more or less enlightened days when the electricity supply industry generally includes large undertakings with extensive town and country areas, which undertakings during the course of years have absorbed smaller and in many instances pioneer concerns, I shall endeavour to trace a condensed history of the progress and development of an authorized undertaking which has been in existence for some 50 years and which to-day renders efficient service to some 23 700 consumers, and moreover generates at least 90 % of its distributed output at peak periods, yet at the same time gives steady and remunerative dividends to its shareholders. This undertaking is the Newcastle and District Electric Lighting Co., Ltd.

The company was actually brought into existence by the Hon. C. A. (later Sir Charles) Parsons, who no doubt made its power station an experimental ground for the development of his steam turbines, as the records show that quite a number of machines passed through the company's hands before more or less permanent plant was established.

The company was registered as a limited company in January, 1889, and commenced operation in the general supply of electricity under the terms of a Provisional Order dated July, 1891. Then, as now, a Provisional Order was granted by the then Board of Trade for a specified area which was further defined by determining certain streets or parts of streets throughout which mains were to be laid within 2 years of the date of the order. This liability meant the outlay of considerable expenditure in providing mains, and further necessitated the exercise of considerable patience in attracting consumers along such routes.

In 1902 the company extended its operations into the Newburn area under a Provisional Order. In 1904 the undertaking was extended in the Benwell and Fenham area by an arrangement with the then Benwell and Fenham Urban District Council. This area was merged into Newcastle later in the same year. With this combination the company's area comprised the west end of the city and the country to the west to the boundary of the Newburn Urban District Council at Throckley, and covered a strip approximately 2 miles wide by 6 miles long on the north side of the river, an area of approximately 13 square miles.

At this stage it might be of interest to mention some of the officials and staff of the company, to show that the destinies of this then-growing concern were controlled with practically unbroken continuity.

The first chairman of the company was Mr. John D. Milburn, who was succeeded on his death by Mr. J. B. Simpson, the father of the present chairman, Col. Sir Frank R. Simpson. The first managing director was the Hon. Charles A. Parsons, who resigned this position in 1902 but remained a director till 1909, when he gave up these duties to devote his energies to the development of his Heaton and Wallsend works. The Hon. Charles A. Parsons was succeeded by Mr. W. D. Hunter, managing director and chief engineer, who came from Messrs. Clarke, Chapman, and was succeeded in 1917 by Mr. N. S. Tennant, M.Sc., the present general manager and engineer.

It will be of interest to recall that Mr. Hunter was Honorary Secretary of this Centre from 1905–7, and Mr. Mew, the company's accountant, was Assistant Secretary during the same period.

In regard to the other officials and staff of the company, the records of long service are somewhat unique, in fact quite a large percentage have spent practically the whole of their working lives in the employ of the company.

The first offices of the company were established in Grainger Street West, and consisted of one room, two chairs, and a table. In 1928 the offices were removed to more commodious premises at 81 Westgate Road, where the management, secretarial, engineering, and showroom organizations are accommodated.

GENERAL DEVELOPMENT

I now propose to deal with the development of the undertaking's operations and to delineate briefly the progress of the various sections, taking first the power stations in chronological order.

Forth Banks

This station was started up in November, 1889, and the plant was housed in buildings purchased from Hawthorn, Leslie, and forming a portion of their Forth Banks works, which they had used as their marine engine department before removal to a larger section of their works at St. Peter's.

* Newcastle and District Electric Lighting Company, Ltd.

The steam-raising equipment consisted of 3 Lancashire boilers supplying, in the first instance, four 150-kW, one 100-kW, and two 75-kW single-phase, 80-cycle, 1 000-volt turbo-alternators which provided for 100 volts lighting only, through step-down transformers.

In reaching this stage of initial equipment several types of turbines were tried out, some of which apparently did not have a very long stay in the station. Some of these were radial flow turbines, which were so designed as Messrs. Clarke, Chapman, held the axial-flow patents.

The station was extended by installing three 500-kW single-phase alternators, and later two 400-kW turbo-generators to meet the quickly growing power demand.

The total capacity of this station in 1902 was three 150-kW sets.

The power station was, so to speak, located on the side of a hill in terraced buildings, with the boiler house on the lower level, the engine room at mid level, and the coal bunkers on the top level.

It was only the fact that the turbo-alternators of the above-mentioned sizes and date required only light foundations that enabled the existing buildings to be utilized with comparatively little alteration; Parsons claimed that his turbo-alternator could be installed on the floor of a factory without special foundations.

The coal was delivered by rail from Central Station over a level-crossing in Forth Street to the bunkers in Hawthorn, Leslie's yard at the top level, as aforementioned, and was conveyed by chutes and screw conveyors to the boiler house at the lower level.

The water supply to the station was drawn from the River Tyne through pipes laid in a brick tunnel about 100 yards in length.

Since this station ceased operation in 1904 the engine rooms were used as a general store, apart from certain space taken up by fuse panels controlling the 1 000-volt single-phase feeder system; these have been removed, and such feeders as remain are controlled by oil-immersed switchgear situated in the Close power station.

The cleared space originally occupied by the boiler house is used as one of the emergency coal stores for Close power station.

With the removal of the single-phase fuse gear, the old No. 2 engine room was adapted to accommodate the battery which was removed from the Chronicle Office substation, and at the same time this battery was thoroughly reconditioned and some extra cells were added, the whole battery giving a stand-by on the 480-volt d.c. system of some 900 kW for 1 hour.

It will thus be seen that every endeavour is made to utilize the existing property of the company to its best advantage.

An item which should not be passed over is the fact that one of the first four 150-kW single-phase alternators was designed by the Hon. C. A. Parsons to run as an a.c. or d.c. machine by changing the armature, but there is no definite record of its use other than for alternating current, no doubt owing to the rapid development of d.c. load, necessitating separate turbo-generators.

Close Power Station

This station was commenced in 1902 to supplement and eventually replace the original station at Forth Banks. It was built on a site fronting the Tyne between the river and the Close, a narrow roadway running from the bottom of Forth Banks to the Sandhill on the Quayside.

The site was originally occupied by Messrs. Scott and Mountain before they moved to new works at Gateshead, at which they continued the original name of "Close."

The station was completed in its first stage in 1904, then it housed two 1 000-kW d.c. generators and five 18 000-lb./hour boilers.

Up to 1908 the station was extended in sections by the addition of three 18 000-lb./hour boilers and two 1 500-kW turbo-generators, three 500-kW 80-cycle turbo-alternators being moved from Forth Banks into the engine room.

In 1915 and 1916 the generation of 3-phase 40-cycle power was undertaken, and two 3 000-kW, 6 000-volt turbo-alternators and two 40 000-lb./hour boilers were installed.

A 750-kW rotary convertor and a 500-kW 40/80-cycle frequency-changer were installed to interconnect the various networks.

In recent years a further 18 000-lb./hour boiler has been added and the capacity of one of the 40 000-lb./hour boilers has been raised to 60 000 lb./hour by modification to the setting, and the addition of a water wall and balanced draught stoker.

Detail improvements include a continuous boiler blow-down system and heat exchanger, turbo feed-pump, steam-jet air ejector, and other modifications still proceeding.

The 750-kW rotary convertor has been replaced by two 1 000-kW invertible rotary convertors.

Furthermore, heavy-breaking-capacity 6 000-volt iron-clad switchgear was installed for all machine and feeder circuits when the station was connected to the National Grid system. The 6 000-volt switchgear is housed in a modern switch-house, and is remote electrically controlled from the power-station switchboard.

The switchhouse is divided into two busbar sections with fire screens between each section of busbars as well as the busbar coupler.

The switchgear is designed to deal with a breaking capacity of 250 000 kVA through reactors, and the switch-house is equipped with an efficient emergency oil-drainage scheme and suitable protection of generator and feeder cables against fire risks. In addition it is provided with a CO_2 fire-extinction equipment by which switchgear and cable chambers can be separately charged with the gas smother.

Lemington Power Station

This station was put into commercial operation in 1904. It is situated on the banks of the old river at Lemington, immediately adjacent to the Lemington Glassworks. There was no direct railway siding into the station, the coal being led across a gantry erected from the road-level at the rear.

The initial equipment of this station solely for the supply of direct current to the system network was two 400-kW turbo-generators.

Owing to the establishment of Newburn Power Station, to be referred to later, this station ceased to generate in

1919. It is now used as a substation connected to the a.c. system for supplying direct current through rotary convertors and motor-generators to the Corporation tramways in that district.

Newburn Power Station

This station was situated on land leased from John Spencer and Son, Ltd., being part of their steel-works.

It was inaugurated in 1908 as a waste-heat station to use the exhaust steam available from the mill reciprocating engines situated in the steel-works, and the initial plant consisted of one 750-kW exhaust-steam turbo-generator.

The exhaust-steam receivers were situated on open ground immediately behind the engine house. The exhaust-steam plant was extended in 1915 by the addition of one 2 000-kW 6 000-volt mixed-pressure turbo-alternator supplemented, when necessary, by two hand-fired boilers each with a capacity of 20 000 lb./hour; also two 750-kW rotary convertors were added.

Due to the closing down of the rolling mills at Spencer's steel-works in 1924, the turbo-alternator was not further used, and in consequence of the recent change-over to 50 cycles the station was completely closed down and has now been dismantled.

In concluding these notes on the Newburn station, attention should be drawn to the fact that there are some portions of the original steel-works still doing good service, and these are an offshoot of the old firm who continue to manufacture heavy springs, and in whose works the Newcastle and District Electric Lighting Co. maintain a rotary-convertor substation connected to the a.c. high-voltage system; also a firm of sisal cordage manufacturers who take a supply from the high-voltage system.

DISTRIBUTION

80-Cycle System

As mentioned in the notes on the original station, the early system of supply was single-phase, 80 cycles, generated and transmitted at 1 000 volts and stepped down to 100 volts at consumers' premises or to 250 volts at one or two substations.

The transmission system consisted of single-conductor rubber-covered cables drawn into iron pipes, and the service branches to these cables were made in underground street boxes spaced at frequent intervals, by spliced and vulcanized joints on to the main cable.

The switching of the 1 000-volt system was by means of air-break switches at the power station, and the protection at this point and on consumers' premises was by various types of fuses.

The 1 000-volt consumers' services and transformers have been changed to ironclad enclosures, and efficient isolating switchgear has been provided.

The 1 000-volt transmission system, which is now of limited extent, is controlled from Close power station through oil-immersed overload circuit-breakers.

D.C. System

The 480-volt d.c. system, which was extensively laid throughout the city area, consisted of rubber and also paper bitumen-insulated single-conductor cables laid in earthenware troughs as well as in cast-iron troughs, the troughs being filled in with bitumen, and this system gave efficient service for many years.

However, with the course of time some portions of these mains which were subject to continuously increasing traffic vibration and the movement of ground have needed replacement, which in recent years has been carried out with paper-insulated and armoured cable. In some instances these replacements have been made by using 4-core cables with the conductors bunched in parallel so as to give the required capacity and to be available as low-voltage a.c. distributor cable in the future. All present-day extensions are made with paper-insulated and armoured cable.

The control of the d.c. cable system was by means of underground street boxes equipped with stud contacts. In later years a number of these underground boxes have been replaced by overground street pillars containing links and fuses, which road alterations have necessitated, and also to afford quicker means of isolation of sections under emergency.

The principal rotary-convertor substations are St. James Street and Seaham Street, which during recent years have been added to and brought up to date with 50-cycle plant.

The St. James Street substation was started up in 1928 and was extended to be sound-proof, and could run as a more or less hermetically sealed chamber with air drawn through ducts to the rotaries and their transformers by electrically-driven fans, but as this substation causes very little noise in the vicinity this feature has very seldom been brought into use.

Although the normal policy is to minimize connections to the d.c. system in favour of the rapidly growing a.c. system, in view of the extensive mains, the capital expended thereon, and furthermore the high cost of changing consumers' plant over to alternating current, the company's policy, at the moment, is to retain the d.c. system, but to maintain this in a thoroughly efficient and reliable condition and, where necessary to extend, to do so in a manner that allows for a change-over to alternating current at a later date.

Great attention has been paid to efficient earthing and to renew solid services by armoured cable, as in course of time these old services have been liable to deteriorate.

High-voltage System

The alternating-current 6-kV distribution system is generally comprised of ring main and spur feeders. The supply is transmitted to 34 static and 5 rotary substations, two of the former being of the outdoor type and the remainder of the indoor type. Provision has been made in a number of cases for the housing of substation equipment in consumers' buildings, with an agreement to provide supply for other consumers in the vicinity. In the majority of substations transformers are installed outdoors.

With the exception of the two outdoor substations having metal-clad switch-fuse units, metal-clad compound-filled switchgear with direct-operated automatic oil circuit-breakers are installed.

Connection to the grid necessitated modification where rupturing capacity of the switchgear was inadequate to

meet the new conditions. The rapid operation of the feeder circuit-breaker is ensured by the use of the Merz–Price split-pilot protective system backed up with overload protection. The protection of the transformers is effected by means of overload and earth-leakage protective relays.

With one exception, consisting of two air-cooled units, transformers are of the oil-cooled type fitted with off-load tap-changing equipment. During recent years it has been the practice to standardize upon transformers of convenient capacity, chiefly 300 kVA.

Where necessary the transformers are arranged to eliminate the transmission of excessive noise of adjoining premises.

The 6 000-volt overhead lines are not extensive, being limited to $1\frac{3}{4}$ miles.

Low-voltage System

The low-voltage system is at 440/250 volts, 3-phase, 4-wire. The feeder, distributor, and service cables, are of paper-insulated lead-served single-wire-armoured type, with the exception of certain small areas where the original 3-wire d.c. and 80-cycle 2-wire solid systems are utilized for a.c. supply.

Feeder cables are laid direct in the soil to overground link and fuse street pillars, and underground link and fuse boxes, from which distributors are fed through suitable protective fuses. The layout is designed with a view to minimizing the extent of an interruption of supply caused by a fault.

Normally the low-voltage systems are divided into areas each supplied from its own substation, arrangement being made, however, for interconnecting low-voltage areas.

The low-tension metal-clad substation switchgear installed at the substations is of the switch-fuse type, metering equipment being installed on the transformer low-voltage panel to record the maximum demand and the units supplied through the substation. There are also installed earth-leakage recording and indicating ammeters at respective substations.

Recent practice has been to afford protection from low-voltage faults by means of high-rupturing-capacity cartridge fuses.

In a number of small areas the eaves wiring system has been adopted.

CHANGE OF FREQUENCY

It is interesting to record that the change-over of the company's 40-cycle system to 50 cycles under the provisions of the 1926 Act entailed the change-over of consumers' apparatus and the company's switchgear and generating plant at a cost of £136 782, some 13 500 consumers being affected.

The change-over of consumers on an inter-frequency basis was carried out as a gradual process during a few years prior to the initial connection of the company's system to the grid, when the whole of the company's a.c. generating plant was closed down and a supply was continuously maintained from the grid during the power-station change-over work.

The actual change-over of the company's system and consumers connected thereto was completed in November, 1936, and was actually effected in a period of 21 days without any interruption of the supply and with little or no inconvenience to consumers.

METERS

Although metering is a specialized branch, brief mention should be made of the progressive activities of the department. At the inception of the company the work was largely empirical and meters were large and unwieldy though simple in conception and ingenious in construction. They were confined initially to attempts at measuring quantity rather than energy, whilst coin-operated and multi-tariff mechanisms were unknown.

At the end of the first year of the company's existence some 50 house-service meters were in use, all of the type invented by Prof. Forbes, in which a light and carefully balanced fan of mica was suspended above a small net of wires carrying the current to be measured, the heated air causing rotation of the fan on rising. This rotation was transmitted to a registering counter and the whole assembly was enclosed by a glass bell cover. These instruments were obviously subject to liberal and indeterminate errors, but sufficed for the requirements of the period until the advent of the universal type invented by Dr. Aron, based on the difference in rate between two pendulums, one being influenced by the commodity to be measured.

Testing methods in those days were also necessarily crude, loading being accomplished directly from the mains via a calibrated ammeter and water resistance for control, whilst the potential coils, if any, were of course excited continuously, also directly from the supply. This method was costly in operation and limited in application to meters of 100 amperes capacity.

The present-day methods employed are the now well-known phantom test loading, in which the potential coils are energized from a low-current circuit and the current coils from a low-voltage source, via the medium of transformers in a.c. work and secondary battery in d.c. practice, resulting in superior control and economy. Testing a 100-ampere, 250-volt meter by the original scheme would require 25 kW, whereas the same result is achieved by phantom load with an expenditure of energy of merely 1·7 kW, or for a 1 000-ampere meter 3·5 kW.

Some 27 000 house-service meters are now in use on the company's system, and recently all ordinary consumers' meters calibrated and tested by the department are certified before issue by an Electricity Commissioner's Examiner as required by the new Electricity Supply (Meters) Act, 1936.

GENERAL NOTES AND STATISTICS

Lengths of Mains and Distributors:—

1 000 volts, 80 cycles, 19 miles.
D.C., 480 volts, 32 miles.
High-voltage alternating current, 6 000 volts, 40 miles.
Low-voltage alternating current, 440 volts, 143 miles.
High-voltage overhead lines, $1\frac{3}{4}$ miles.
Number of consumers at the 31st December, 1937:—

On a.c. system	20 350
On d.c. system	3 350
	23 700

For the operation and maintenance of the company's systems, and for consumers' installations, the staff are required to comply with a stringent set of instructions to ensure general safety, and only persons certified as "authorized" are allowed to carry out responsible duties.

The company maintains an efficient and profitable showroom, as well as a separate cookery demonstration kitchen which renders an up-to-date service to its consumers.

Three of the earlier machines covered by the previous power station notes have found well-earned and suitable resting places as follows:—

100-kW, 80-cycle radial-flow turbo-alternator at Dublin University.

100-kW, 80-cycle radial-flow turbo-alternator at Manchester University.

125-kW axial-flow turbo-generator at Newcastle Corporation Industrial Museum.

CONCLUSION

In conclusion I have to express my grateful thanks to the chairman and directors of the Newcastle and District Electric Lighting Co., Ltd., for permission to use the records of the Company, and to reproduce old photographs and to take new ones for this purpose,* to Mr. N. S. Tennant, the general manager and engineer of the company, and to the staff for the help given in collecting information and presenting it in this form, and particularly to Mr. S. N. Willey and Mr. N. M. Taylor for preparing lantern slides and delving into many backwaters in search of interesting material.

* Not reproduced in the *Journal*.

IRISH CENTRE: CHAIRMAN'S ADDRESS

By J. W. O'NEILL, Member.*

"THE TELEPHONE SYSTEM OF EIRE"

(ABSTRACT *of Address delivered at* DUBLIN, *27th October*, 1938.)

Records of the very early days of the service in Eire are scarce, and I am indebted to members and ex-members of the staff for particulars of the conditions in those times. The telephone was invented by Graham Bell in 1876. The first commercial exchange was opened in New Haven in 1878, and the first exchange in London in 1879. The United Telephone Co., the pioneers in this country, opened the first exchange in Dublin at Commercial Buildings, Dame Street, in 1880. The business was taken over by the Telephone Co. of Ireland in 1883.

The type of board and the method of operating were very different from present-day practice. In the first place the subscribers did not expect to be answered when they rang up but waited patiently until they were called back by the telephonist. The principal operators stood at the boards but only answered some of the calls. The others were transferred to auxiliary speaking operators seated at tables who re-called the subscribers, ascertained their requirements, and told the switching operators what connections were to be made. There were two auxiliary operators for each switching operator.

In the busy hour the exchange was rather noisy as all instructions were passed by direct speech and not by telephone. In 1893 the Telephone Co. of Ireland was taken over by the National Telephone Co., who replaced the original boards by a 12-position multiple switchboard which also had some novel features. The cords came down from an overhead canopy and the ringing generators were worked by sewing-machine treadles. Multiple working was novel and apparently double connections were feared, for an alarm was installed which operated a buzzer on the position if a telephonist missed the "engaged" test and plugged in on an engaged line. The subscribers' circuits from Commercial Buildings were all single-wire and were carried by roof standards and very high poles (reaching 90 ft. on some of the routes).

The exchange and the line plant becoming inadequate to meet the growing demand, the National Telephone Co. planned a complete new system for Dublin. The circuits were made metallic, an extensive underground cable network was laid down to replace the open routes in the city, and a building was erected at Crown Alley to house a new switchboard which was brought into service at Easter, 1900. This switchboard can be regarded as the final development of the magneto system, which was then being supplanted for large exchanges by the central battery system. The calling was by magneto but the clearing was automatic on replacing the handset. Only three other switchboards of this type appear to have been installed, namely at Belfast, Bradford, and at Hop Exchange, London. The Dublin board gave long and faithful service; it was extended from time to time, and was not finally displaced until 1930, on the completion of the change-over to automatic working. The building is still in use and at present houses an automatic unit of the Dublin network.

In the early days the trunk service was very tenuous. Two circuits connected Dublin with Belfast, and one circuit to Dublin was shared between Cork and Limerick. Waterford had its first connection via Wexford and the coast line.

There were several isolated exchanges; for example, Galway exchange was opened in 1897 but was not connected to the trunk system until 1914. The main trunk lines were taken over by the State in 1896, and to improve transmission a heavy-gauge circuit (800 lb. per mile) was run between Dublin and Belfast. The only cross-Channel connection was via Belfast, a submarine cable having been laid from Donaghadee to Port Mora in 1893 to take advantage of the short crossing of the North Channel. Amplifiers were unknown and the unaided output of the microphone had to serve for long-distance calls, yet with care it was possible to carry on commercial conversations between Cork and London.

The whole of the plant of the National Telephone Co. was acquired by the Post Office in 1912. Since then I have had personal acquaintance with the system in Eire. In the last few years of its life the company was naturally reluctant to incur any expenditure which could possibly be postponed, consequently when the Post Office took over the system there were large arrears of renewal and development work to be undertaken. This work was well in hand when the Great War intervened and slowed down progress.

A direct telephone cable between Dublin and Wales was, however, laid in 1913. The distance was then exceptionally long for a submarine telephone cable, so a special coil-loaded gutta-percha cable was used. It was one of the first of its type and gave very useful service, but was very unlucky as regards damage by ships' anchors and other causes, and after being repaired many times is now being replaced. After the Armistice, major works proceeded principally in the direction of extensions of underground in Dublin and the larger provincial towns, and extension of the main trunks. But again the Anglo-Irish and civil wars intervened. At the close of hostilities there was a considerable amount of damage to plant to

* Department of Posts and Telegraphs, Eire.

make good, and it was necessary to consider the planning of the system for the country as a whole.

The design of a telephone system for a country depends on local conditions and requirements. A plan which would be satisfactory and economical for one administration might be unsatisfactory or wasteful for another. Thus arise the differences in fundamental design seen between the systems of different countries—each is planned to meet best the local needs.

There must, of course, be certain agreed standards of transmission, operation, etc., to permit of international calls and world-wide service. It is the function of the C.C.I. to formulate these. This Committee, which has rendered possible world-wide telephone calls, whilst at the same time leaving to each administration the fullest possible liberty in the design of its national system, was formed as an outcome of the Presidential Address delivered in 1923 by Mr. Frank Gill, who, when stationed in Dublin many years before, designed the original Crown Alley system.

In Eire we have three very definite local conditions:—

(1) The majority of the users are concentrated within a radius of 10 miles from Dublin.

(2) The other important centres such as Cork, Limerick, and Waterford, are situated at distances of over 100 miles, and the towns met en route are small.

(3) The smaller towns and the rural parts of the country have a sparse telephone population, but there is an insistent demand for services all over the country and many of the subscribers in rural areas are important users of the long-distance system.

The telephone service here, although State-owned, is considered as a commercial enterprise. Extensions of the system are charged to capital, and the income from fees, rentals, etc., has to cover all operating and maintenance expenses, provide an adequate sum annually for depreciation, and pay 5 % interest on the outstanding capital. If after this a surplus remains it is considered a profit. If the full interest has not been earned the deficiency is considered a loss. The results of each year's trading are published in the commercial accounts. A survey of these shows that since 1922 the profits exceed the losses.

From a consideration of our local conditions it can be concluded that on the broadest terms our requirements are:—

(1) A high-grade urban service in Dublin and the more important provincial cities.

(2) An adequate but economical long-distance service from Dublin to the main provincial centres.

(3) A widespread network covering the small towns and rural parts built at a cost which will enable reasonable rentals to be quoted, and giving the best service that can be provided under these conditions.

I propose to speak generally of these three problems. Considering, first, Dublin and its suburbs, here we have an area with considerable telephone density. The traffic is heavy, especially on business lines, but is nearly all confined to the area as there is no other large group of subscribers within reasonable distance. The conditions demand, and the traffic justifies, the provision of a high-grade local service. Different methods of serving the area were considered and the investigation showed that the most economical method of providing the required grade of service was by means of an automatic multi-office system.

The design adopted was on the basis that the area could be dealt with piecemeal as the existing manual exchange became inadequate or required renewal.

As a first step in order to accustom the subscribers to the new system and to provide opportunities for training the maintenance staff, work was commenced on two comparatively small automatic exchanges, and the first of these was brought into service in 1927. The subscribers found no difficulty in operating the dials, and as it was desired to ascertain their reaction to automatic working a plebiscite was taken of all whose instruments had been changed. The result was a 95 % vote in favour of the new system.

After a short experience of the working of these two exchanges an International Committee was appointed to report on the Post Office proposals for dealing with the remainder of the Dublin area. After investigation the proposals were adopted without modification and the work of conversion to automatic was proceeded with as circumstances justified.

The centre of the city was first dealt with, the manual exchange at Crown Alley being closed in 1930. Subsequently the Rathmines and Terenure areas were changed over, and at a later stage the Drumcondra, Clontarf, and Dundrum areas. Work is at present proceeding on an automatic exchange for the areas served by the present Blackrock, Dun Laoghaire, Foxrock, and Dalkey exchanges, and it is expected that these will be changed to automatic working in the autumn of 1939. By that time 90 % of the telephones within a 10-mile radius of College Green will be connected to automatic exchanges, or about 60 % of the telephones in the country.

The design of the local network for the Greater Dublin area will serve as an illustration of one of the fundamental aspects of telephone engineering. Almost any telephone problem can be solved technically in a number of ways. The correct solution is the one which will be most economical in the long run. It is not easy to select this when growth for a period of 15 years has to be foreseen, and especially when the alternatives have different proportions of line and apparatus costs. Wire and cable costs depend on the prices of raw materials, lead and copper, whilst apparatus prices depend on manufacturing costs.

There is no relation between the long-period fluctuations in prices of raw materials and in manufacturing costs.

Another factor is that improvements are to be expected in apparatus which may reduce the cost of the equipment or even enable economies to be effected in the line plant. It is desirable, therefore, that a basic scheme should be as flexible as possible, to secure the best advantage from varying price levels.

In the twenties the price of copper and lead were high and the exchange equipment used set a limit on the resistance of subscribers' lines. Consequently it was desirable to keep the lines reasonably short, and economic studies showed that the best solution involved opening a number of satellite exchanges.

When the work came to be carried out, conditions had changed. There had been a great fall in the prices of metals and consequently in cable costs, and improvements had been made in the exchange equipment which enabled lines of higher resistance to be used. Consequently it became more economical to cable all the subscribers' lines in the proposed satellite areas directly to the main exchanges.

It is, of course, possible that in the future relative costs may change or other conditions may arise which would render it economic to open satellite exchanges for parts of these areas. If so this can be done with a minimum of rearrangement.

For the Greater Dublin automatic network unit-fee metering had been adopted as it was found that, owing to the greater preponderance of short-distance calls, multi-metering would not be economical.

The telephone conditions in the city of Cork are comparable with those in Dublin, and the installation of an automatic system there had been approved and will be put in hand soon.

Trunk communication can be effected either by open-wire lines, by cables, or by carrier circuits guided by open wires or cables. When the circuits required are relatively few and short, open-wire lines have the advantage. When the number of circuits between two points is considerable it is more economical to use cable, but unless the number of circuits is large the first cost per working circuit is high.

A third method of providing long-distance trunk circuits is by means of carrier-current working. This may be considered as wireless technique applied to wires which are used to guide the waves, and, as with wireless, different carrier frequencies are used to provide a number of channels. The incoming frequencies are received on tuned circuits which separate and convert them to independent voice-frequency circuits.

Carrier-current working can be applied to open-wire or cable circuits. The development of cable carrier has been ably described in a recent paper read before The Institution.*

When applied to cables the advantages of carrier are mainly economic as high-efficiency circuits can be obtained by voice-frequency working, but when applied to open lines carrier has the additional advantage that high-grade circuits can be provided over distances which it would be impracticable to cover adequately with ordinary open-wire transmission.

In Eire the distances between Dublin and the more important provincial centres are generally over 100 miles. The number of circuits required is comparatively small and there are few intermediate points of importance on the routes. The distances are too great to render it economical to provide high-grade circuits by heavy-gauge open wires, and the number of circuits is too small to justify cable. Therefore a system of 3-channel carrier-current working on open wires has been adopted for the backbone trunk circuits. Studies made in connection with planning carrier schemes under our conditions—viz. that the physical circuits used as guides are required for other purposes, and that the existing wires usually require to be re-transposed—indicate that carrier working is economical for high-grade circuits when the distance is more than 80 miles, and in specially favourable conditions for distances as short as 60 miles. I think that the tendency will be for the minimum distance to diminish and that in future carrier working may be economical even for distances less than 60 miles.

The use of existing circuits for guides makes the cost of the carrier system substantially independent of the distance between the terminals, up to the limits likely to be met with in this country.

Open-wire carrier circuits have been in use here for over 6 years and the results have been very satisfactory.

Provided adequate care is taken in the installation, system faults are rare and day-to-day maintenance is small. The valves are tested regularly for emission and replaced as soon as a drop is noticed, and failures due to valves burning out in service are very rare. The life of the valves used is very long. Some of the original ones on the first system which have been in almost continuous service for over 6 years show no signs of decrepitude. When the first system was installed here great care was taken with the line maintenance as it was feared that slight inequalities might affect the carrier working. The test came in the following winter when the route was completely wrecked by a blizzard. A temporary circuit was quickly put through between the terminal points, using any available plant on devious alternative routes, but the transmission loss was so great that commercial speech was not possible. As an experiment the carrier was tried on the line, and rather to our surprise it was possible to talk over it. The transmitting and receiving amplification was then increased at both ends and 3 zero-loss circuits were obtained.

These 3-channel systems have immense reserves of power and in emergencies are capable of giving commercial service over very difficult circuits.

When several carrier systems run on the same route the requirements are a little more severe and special measures are taken to prevent overhearing, as at the higher frequencies used there is greater liability to cross-talk. The guide circuits are re-transposed at more frequent intervals on a definite design, and it has been found that this prevents any observable overhearing. In fact cases have occurred in which a fault on a guide circuit, sufficient to prevent commercial speech, has had no noticeable effect on its own or on adjacent carrier systems.

However, even when there is only one carrier system on a route it is desirable, for best results, to provide carrier transpositions, otherwise slight interference may be experienced from long-wave wireless telegraph stations.

We are also applying carrier working to submarine cables. The steady growth of cross-channel traffic overloaded the direct Dublin–Wales cable, and in 1932 additional circuits were provided via Belfast. The traffic still grew, and it was decided in conjunction with the British administration to lay a pair of cables from Dublin to Wales. The first was laid in September, 1937, and the second in August, 1938. These cables are of a novel type which has been evolved within the last few years. They consist of a central conductor covered by

* A. S. Angwin and R. A. Mack: *Journal I.E.E.*, 1937, vol. 81, p. 573.

approximately $\frac{1}{4}$ in. of special waterproof low-capacitance insulation, which in turn is surrounded by layers of copper tape forming the earth lead.

The whole is served with an armouring of steel wires in the usual manner. These cables are designed to give the lowest possible loss at high frequencies, as they are to be the go-and-return conductors of a carrier system, at present being installed, which it is hoped will be available for service within 2 or 3 months. The system will provide 16 channels at the outset, working on frequencies up to 60 kc./sec., the band-width for each telephone channel being 4 kc. at the higher frequencies and 3 kc. at the lower. At a later stage it is expected that additional channels will be obtained at still higher frequencies.

As the first of the new cables was ready before the permanent terminal equipment was available, an open-wire 3-channel carrier system was tried on it experimentally. The line make-up was most unsuitable for the system, consisting of 10 miles open wire, then 65 miles of submarine cable followed by 20 miles of open wire. However, with but minor modifications, satisfactory results were obtained and the 3 additional circuits provided were quickly filled with traffic.

The majority of the calls on our trunk circuits are incoming to Dublin, and the bulk of these are for automatic numbers. To meet this condition a circuit was designed locally which enabled the distant telephonist, say at Kilkenny or Athlone, to dial the Dublin automatic numbers directly. This speeded up the service appreciably and enabled the trunk lines to carry more calls, but the system is only applicable to physical voice-frequency circuits where a wire is available to carry the d.c. signalling.

The normal carrier signalling arrangements involve calling in a telephonist at Dublin to dial the number. This causes delay and loss of circuit time. A system which will give full dialling facilities on carrier circuits has been designed and tried out experimentally, and is now being installed on all internal carrier circuits terminating at Dublin. It employs timed pulses of two frequencies of 600 and 750 cycles either together or separately, and in addition to dialling it provides full signalling facilities, e.g. the transmission and acknowledgement of conditions such as calling, clearing, busy, etc. Special problems arise in connection with voice-frequency signalling systems. One is that the circuits must be immune from false operation when the signalling frequencies used occur in speech. Another is that when a number of circuits are connected in tandem in the speaking condition, d.c. signals can be confined to each section of the chain, whereas a voice-frequency signal from one end must of necessity go right through to the other, and unless special precautions are taken trouble may be caused, especially where international links make up the chain.

The third aspect of our system of which I propose to speak may be called the rural problem. There has been an insistent demand for the extension of the telephone service throughout the country. In the United States great use is made of the party-line system for rural areas. The system is economical in plant and operating costs and in America gives satisfactory service, but attempts made to sell party-line service here have been utter failures. The prospective subscribers simply will not tolerate the idea that other users connected to the same line can listen-in on their calls.

If the telephone density of rural area is comparatively high and there is a local community of interest, a fully automatic system can be justified economically, and such networks have been constructed by several countries.

Here the telephone density is far too low to justify fully automatic working throughout, and therefore the extension of the system to the rural parts of the country has been on a manual basis. By 1922 the trunk service had reached most of the larger and a number of the smaller towns but the rural areas were practically untouched except in so far as call offices had been opened at a number of rural post offices, and the total normal service areas of all exchanges amounted to only $2\frac{1}{2}$ % of the area of the country.

Since then the lines have been gradually extended throughout the country, numerous small exchanges have been opened, and the normal service area has been extended to a radius of three miles.

The present position is that 60 % of the country is now within the normal service area and of the remainder a large proportion is very sparsely populated, being mountain or other uncultivated land.

The problem of giving a reasonably good service to these numerous and very small exchanges at economic cost is a very difficult one. The junction lines are long and it is frequently necessary to connect several small exchanges to the one junction, thus degrading transmission. A new type of magneto-telephone giving greatly improved transmission has been introduced and is being installed at all the (electrically) more remote exchanges. The provision of backbone carrier trunk circuits with practically zero loss to the more important provincial centres has improved conditions for the smaller exchanges centred on these. The transmission problem is on the way to being solved, and soon almost all exchanges, however small, will have unlimited trunk facilities.

The switching problem remains. The cost per line for operating small manual exchanges is considerable even when only a 12-hour service is given. The operating cost of 24-hours' service would be prohibitive, therefore only a 12-hour service can be given. Further, the standards of service, speed of answer, and clearing, etc., which are in force at the larger centres, where trained telephonists are employed, cannot be expected at the really small exchanges, as undivided attention is not given to the switchboard.

The importance of the problem will be realized from the fact that out of a total of some 800 exchanges in the country more than 600 have fewer than 10 subscribers each.

After consideration the conclusion has been reached that the best prospect of a satisfactory solution lies in semi-automatic small exchanges. With this method of working the subscriber has an ordinary manual telephone. When he makes a call his line is automatically switched through on a junction to a distant manual

exchange where an operator answers. Incoming calls are dealt with by the same operator, who can call any subscriber on the rural exchange by dialling over the junction.

The aim is to concentrate at a manual centre the junctions to a number of rural semi-automatic exchanges, and so build up a load which will justify the employment of trained telephonists to give a 24-hour service.

With a semi-automatic system in rural areas reliability is a first consideration and it is considered that it must not be possible for a fault on any subscriber's line, or any mal-operation by the user, to put the whole rural exchange out of action.

Generally only one junction line would be available for these small exchanges, so there is a probability that callers would frequently find this line engaged. It was therefore specified that any calls made while the junction was engaged should be stored and passed on to the remote operator as soon as the line became free.

As at present two manual exchanges are frequently connected to a junction, it was considered desirable that it should be possible to work the semi-automatic exchanges in tandem and that ultimately it might be necessary to work them through a full automatic exchange. With this in view it was decided to make a field experiment with the most complex arrangement foreseen, and, in order to keep the results under close observation, exchanges in the vicinity of Dublin were selected.

The network now under test comprises a full automatic exchange at Malahide, a semi-automatic tandem exchange at Donabate, and terminal semi-automatic exchanges at Rush and Lusk, all working to the manual control centre at Dublin.

When a Rush subscriber rings up, if the junctions are free his line is automatically switched through at Rush, Donabate, and Malahide, to the Dublin controlling board. Should the call be for outside the rural network the telephonist extends it in the ordinary course. If the call is to another subscriber on any of the four rural exchanges the operator dials back over the junction, calling the wanted party. When two subscribers are in conversation the operator can withdraw from the circuit. This sets free the junction to Malahide and puts the call under the control of an automatic timing device which disconnects the lines after the lapse of 6 minutes, should the subscribers not ring off before. The timing is necessary to prevent the rural exchange being held up by very long local calls or by subscribers forgetting to ring off.

Should the junctions be engaged when the Rush subscriber rings up the call is stored for a period of 6 minutes. If the circuits become free within that time the calling line is switched through to the Dublin operator who rings back and calls the subscriber. This facility is provided only on the semi-automatic boards which have at most two junctions and where overlapping of calls is most likely to occur.

The experimental installation has now been in service for over a month. It promises well, but of course a much longer trial will be necessary.

In the time available I have been able to touch briefly on only three main aspects of our telephone system and the fundamental problems to which they give rise. It may be of interest to speculate on the future. Developments in the telephone art are so rapid and far-reaching that it would be rash to assume that present-day practices and methods may not be greatly changed 15 years hence, but in the light of present knowledge it seems to me that for the larger urban areas the plans for automatic networks will take care of any growth that can be foreseen.

For the long-distance service the system of open-wire carrier working will serve economically until such time as the growth of circuits on the more important routes may justify the provision of long-distance cables.

As regards the rural problem, the transmission difficulties will be overcome by the provision of high-efficiency instruments and long-distance circuits, and there is reasonable hope that small semi-automatic exchanges will go a long way towards solving the switching problem.

EAST MIDLAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By T. ROWLAND, Associate Member.*

"SOME CONSIDERATIONS RELATING TO DECENTRALIZATION OF GENERATION"

(ABSTRACT *of Address delivered at* LOUGHBOROUGH, *4th October*, 1938.)

The subject which I have selected for my Address is intended to promote consideration of whether it is desirable and in the best interest of the industry as a whole to continue the process of crowding together very large units of generating plant to form exceptionally large power stations on individual sites, or whether it would not be better to adopt a measure of decentralization, with many power stations of moderate capacity placed as near as practicable to the place where the supply of energy is to be used.

All of us admire the skill of the designers of the largest units of generating plant and the power stations in which they are assembled, as also the enterprise of those who have enabled them to be brought into being, but perhaps in our admiration of such great achievements we are apt to have our attention diverted from another aspect of the matter, namely the question of whether the consumer will be better served in this way.

Getting down to fundamentals, we must recognize that the supply industry exists for the consumer, without whom there would be no supply industry at all; and that any development which is advantageous to the consumer will in the end be good for the supply industry as a whole, and vice versa. By "consumer" I mean the general body of consumers throughout the country, taken as a whole; not individual consumers, or groups of consumers, e.g. the consumers of any one undertaking. It is, of course, quite possible that the consumers of one undertaking might benefit under an arrangement which would be a definite disadvantage to those of other undertakings, whilst on the average all consumers might be at a disadvantage.

From the consumers' point of view there are two primary considerations: first, reliability, i.e. the supply must be available at all times and under all conditions; and second, the cost of energy to the consumer must be such that he can afford to use it.

Concentration of very large blocks of generating plant on individual sites involves lengthy transmission between the generating station and the point of use, which, at any rate when carried overhead, is subject to interference by atmospheric disturbances such as lightning storms, blizzards, etc. It will, I think, be admitted that a supply which is transmitted over, say, 70 miles of 132-kV line, followed by, say, 20 miles of secondary line operating at 33 or 66 kV, and then over a tertiary system at 11 kV, to be finally transformed and distributed at low voltage, is inherently more liable to be interrupted by atmospheric interference than one which is generated at or near to the centre of distribution.

The concentration of large blocks of plant at individual generating stations also introduces difficulties of control which can only be overcome at great expense in outlay for switchgear, owing to the increased value of available short-circuit kVA to be ruptured under fault conditions. These difficulties and the expense entailed do not end at the generating station, but extend throughout the system, even to the consumers' premises, where in certain cases the existing switchgear becomes inadequate for the altered conditions.

Concentrated generation also entails individual outgoing circuits carrying large blocks of load, an interruption to which may involve failure of supply over large areas, with consequent disorganization affecting such vital services as public water supply, sanitation, and transport; whilst interruption of supply to industrial process work not only causes serious inconvenience but may result also in serious loss, as in some cases a considerable amount of the product is rendered valueless and much expense is entailed in restarting the process.

Another disadvantage of the concentration of large blocks of generating plant on individual sites is that of concentrated chimney effluent; this is particularly objectionable where the power station is in the vicinity of a residential area, and it has also been credited with serious injury to agricultural land. The treatment of chimney gases to render them innocuous where their high concentration renders this procedure necessary is very expensive both in capital outlay and in operating cost, and should be avoided wherever possible.

The handling of coal and removal of ashes also present problems which are much more acute with large concentrations of generating plant than in stations of moderate output. In general, where difficulties arise in the layout or operation of power stations of moderate output, they will occur in more acute form in very large ones. The handling of a few hundred tons of coal per day is not a very big problem, but when several thousand tons have to be handled per day the difficulties which may arise are considerably increased. Such matters as interruption of deliveries due to fog interfering with transport become of major importance, whilst the regular transport of coal by sea might suffer severe interference in time of war.

As against the above disadvantages of concentration it must be admitted that large plant units can be constructed to operate at higher thermal efficiency than small units. Super-efficient power stations are, however, relatively expensive to construct. The high pressure and temperature of steam required to obtain high thermal efficiency entail the use of special materials and

* Peterborough Corporation Electric Supply Department.

heavier and more expensive construction, to withstand the greater strain to which the plant is subjected. In consequence such stations are only justified when operated at high load factor, i.e. as base-load stations. Their high thermal efficiency is therefore obtained under what may be described appropriately as artificial conditions, and at the expense of lower efficiency and higher costs in other stations which are allotted low load factors. Under these conditions high thermal efficiency is of somewhat fictitious value from the consumer's point of view. It should be sought, not as an end in itself, but as a means to an end, in this case as a means of reducing the all-in cost of the supply. The reduction in cost due to increased thermal efficiency should outweigh any increase in cost due to the means adopted to attain the higher efficiency, such as increased cost of power station and expenditure on transmission lines required to enable the normal load to be generated by base-load stations.

The following figures, extracted from published information, have a bearing on the question of whether centralized controlled generation offers material advantage in cost to the consumer. In the year 1937 the average coal consumption per unit under controlled (i.e. centralized) generation was about 17 % less than it was in 1932 under independent operation. The average coal consumption per unit was 1·51 lb., and the average price of coal in the South-East England Area was 20s. per ton (this would presumably be above the average price for the whole country). A saving of 17 % in coal consumption was therefore equivalent approximately to a saving of 0·044d. per unit. The average price paid by all consumers throughout the country was 1·085d. per unit, so that reduction of 17 % in coal consumption was equivalent to a reduction of about 4 % in cost to the consumer. It seems reasonable to assume that quite half of this reduction would have been achieved under independent operation, as the thermal efficiency of generating stations was being steadily improved prior to 1932, and there seems to be no reason to suppose that the improvement would not have continued under independent operation; and on this assumption the gain from increased centralization under controlled operation is only about 2 % of the cost to the consumer. It is worth considering whether this 2 % gain is adequate compensation for the disadvantages of concentrated generation, remembering that such "technical hitches" as occur have a very far-reaching influence on prospective consumers.

Another consideration is whether the added expenditure on transmission to enable centralization of generation to be effected is greater or less than the gain due to lower coal consumption; and here there seems to be no room for doubt that up to the present the whole gain due to improved coal consumption is more than absorbed in the costs incurred to make centralization possible.

Another aspect of the question which calls for very serious consideration is the risk of damage resulting from aerial attack in the event of war. The larger the power station, the better and more attractive the target it would present to an enemy, and the more serious would be the result of a successful attack. The destruction by aerial bombardment of one of our largest power stations would be a serious loss. The destruction of several would be a grave disaster. The best provision to make against the occurrence of such a misfortune is obviously decentralization—the use of numerous power stations of moderate capacity, rather than a few very large ones. The more eggs we crowd into each basket and the fewer the number of baskets used, the greater is the risk of a shortage of eggs: a similar remark applies to electricity supply.

One of the greatest defects of the system of many generating stations operating independently which obtained before the advent of the grid was the excessive amount of spare plant maintained in reserve. Through the operation of the grid system the margin of spare plant has been cut down to a reasonable proportion, and in any process of decentralization of generation the grid will be a most valuable asset enabling this reasonable proportion to be maintained and to be universally available.

A further matter which has an important bearing on the question of decentralization is the steady growth of load arising from the more general application of electricity throughout the country. In consequence of this, the number of centres where the load will justify a power station of reasonable capacity is increasing.

Taking all the above-mentioned points into consideration, I am of opinion that it will be more advantageous to develop the supply industry by providing additional generating stations of moderate capacity at such centres near to the point of use rather than by a smaller number of very large power stations with a lengthy system of transmission.

In conclusion, I should like to say to the students and young engineers, in whose welfare this sub-Centre is particularly interested, it is up to you to give careful consideration to such matters as I have mentioned, and to similar questions affecting the electricity supply industry. You should not allow yourselves to be misled by the glamour that always attaches to the big thing because it is big, nor yet by the apparent mediocrity of that which is absolutely reliable. You should form your own opinions on such matters, remembering that by training of this sort you are preparing yourselves to be the leaders of the future.

DEVON AND CORNWALL SUB-CENTRE: CHAIRMAN'S ADDRESS

By H. MIDGLEY, M.Sc., Member.*

(*Address delivered at* PLYMOUTH, *12th October*, 1938.)

THE DEVON AND CORNWALL SUB-CENTRE

To be elected Chairman of a Centre or Sub-Centre of The Institution is a very high honour, whilst, in addition, to be the first Chairman of a new Sub-Centre falls to the lot of very few members. I feel, therefore, particularly grateful to you for electing me as the first Chairman of this Sub-Centre, and I can assure you that I shall do all in my power to further the interests of The Institution and of this Sub-Centre that is an integral part of The Institution with which we all are proud to be associated.

It will, I think, be of interest if I very briefly refer to the reasons which led a number of us to endeavour to set up a Sub-Centre in this district. The Institution is an organization for the purpose of promoting technical association and intercourse amongst its members. Whilst having centralized control it is based on a large measure of de-centralization, and for this purpose there are 10 Local Centres each with its own Committee arranging its own meetings at which papers submitted to The Institution may be read and discussed, all local discussions being printed in the *Journal*. In addition there are 8 Sub-Centres, which in general comprise a smaller number of members than are contained in a Centre, and these Sub-Centres are, with two exceptions, under the aegis of a Local Centre.

Each member of every grade of The Institution is allocated to one or other Centre or Sub-Centre, the allocation in general being based on geographical considerations.

Those members of The Institution living in Devon and Cornwall have hitherto been associated with the Western Centre, the majority of whose meetings have been held in Bristol or Cardiff, except that one meeting per session has usually been in the South Devon district.

Bristol being 120 miles from Plymouth, and Cardiff considerably farther, it is difficult for some and impossible for most members of The Institution living in Devon or Cornwall to take advantage of the Western Centre, and those of us who have been responsible for the setting up of this Sub-Centre felt that it would be to the advantage both of The Institution and of the local members if a Sub-Centre were formed.

A meeting was held in Plymouth on the 11th March, 1936, to consider the matter, and at this meeting it was unanimously decided to present a petition for the formation of a Sub-Centre. This petition, which was signed by 40 members, was in due course considered by the Committee of the Western Centre. Whilst this Committee were in full sympathy with our views there was an element of doubt as to whether the necessary support for the continuance of the Sub-Centre would be forthcoming. It was, therefore, decided to defer the matter for a year, but to hold a sufficient number of meetings in this district to test the support for the project. These meetings were held during the session 1936–7, two meetings being held at Plymouth and one at Exeter.

After considering the attendances at these meetings, the Western Centre Committee reported favourably to the Council regarding our petition, and in the early autumn of 1937 this petition was granted and the Devon and Cornwall Sub-Centre set up.

It being then too late to make the arrangements necessary for a complete session of the new Sub-Centre, it was decided that an Interim Committee should carry on the work for the remainder of the Session, and that the Sub-Centre should be in full operation for the Session of 1938–9. To-night's meeting is, therefore, the formal commencement of the new Sub-Centre.

With regard to the Committee who will deal with the arrangements for the operation of the Sub-Centre, it is the usual practice to elect members for 3 years. If, therefore, the full Committee were elected immediately we should be faced with the necessity of a complete change in personnel in 3 years time, an arrangement which would be extremely unsatisfactory.

It has therefore been decided to elect only a proportion of the total membership of the Committee for the current session, adding further members next session and bringing it up to full strength in the third session. This arrangement should produce the necessary continuity of membership which is so essential in such an organization.

It is proposed by the Committee that the meetings each session should be divided between Plymouth, Torquay, Exeter, and Cornwall, the majority of the meetings being held adjacent to the town at which the Chairman is resident. This will mean that for this session the majority of the meetings will be held in Plymouth. In future sessions the venue of the majority of the meetings will similarly depend upon the residence of the Chairman.

At this point I should like to pay a tribute to the work of Mr. W. A. Gallon, who was Secretary of the Negotiating Committee and, later, Secretary of the Interim Committee. Mr. Gallon's assistance has been invaluable, particularly in view of his experience as Secretary and as Chairman of the Tees-Side Sub-Centre, and we very much regret that, consequent upon his leaving Plymouth to take up an appointment at Southampton, he has had to sever his connection with this Sub-Centre. In his place the Committee have, as you are doubtless aware, appointed Mr. F. C. Isaac as Hon. Secretary.

THE EDUCATION AND TRAINING OF ENGINEERS

It is usual for the Chairman of a Centre or Sub-Centre to deliver at the first meeting of the session an address

* Plymouth Corporation Electricity Department.

upon some subject in which he is particularly interested. I have a keen interest in the education and training of engineers, and I am confident that this subject is very suitable for the inaugural meeting of a new Sub-Centre, as one of the aims of The Institution is the education of engineers, using the word "education" in its broadest sense, and this aim is assisted largely by the association between engineers which results from the meetings of the Centres and Sub-Centres.

I assume at the outset that you will all agree that it is our duty to utilize to the full the intellectual powers with which we are endowed. If you do not agree with this, then of course you will not agree with my succeeding remarks, but I suggest that as arguments for or against my primary assumption are a matter of ethics rather than engineering they are therefore outside the scope of my address.

I would, however, submit that engineering training is becoming more and more essential for the country which wishes to retain the world's markets, for the firms and undertakings which wish to retain their place in the commercial world, and for the individuals who wish to obtain those benefits and amenities which, we generally assume, result from increased remuneration.

It is very noticeable that engineering products are becoming more and more the outcome of highly developed knowledge, a conclusion which is obvious even if we review only the last 20 years. For example, almost any advanced engineering student could design and make an electric motor which would run and probably run satisfactorily, but such a motor might be far from adequate for competition in the commercial markets of to-day. These markets call for the highest possible efficiency, the minimum possible weight and size for the power developed, absolutely reliable construction, and capability of withstanding constant use and misuse.

There is consequently keen competition between one manufacturer and another to obtain these qualities, which necessitate the highest possible degree of engineering skill on the part of the staffs engaged in design and construction. Hence the engineering student would not be qualified to act as the designer to a firm engaged in the commercial construction of electric motors if he had not an amount of training and experience beyond the scope of the very best of technical colleges.

The same argument applies to all engineering products which are becoming the outcome of more and more highly developed knowledge, with the result that the costs of research, design, and inspection, form an increasing percentage of the total cost.

Whilst this is noticeable in all sections of engineering, perhaps the outstanding example is that of steam turbines, where the amount of research and inspection now carried out is far in excess of that even contemplated in immediate post-war days.

These remarks must not be construed as being in the least critical of the ability and knowledge of engineers of earlier generations, but rather the reverse. As an example may be quoted the electricity supply engineers of 40 years ago who were faced with problems which would probably puzzle many a modern engineer, and lacking the technical knowledge available to-day they had to rely to a considerable extent upon their initiative in dealing with the unknown and the unforeseen. Now, however, the extent of knowledge of engineering science available is so great, and the numbers employed in the engineering industry are growing to such an extent, that the necessity for extension of engineering education is becoming increasingly important every year.

At this stage it may be of interest to consider the very diverse material available for education and training. We have the trade apprentice with ambition but limited means, the public schoolboy whose parents are prepared to spend almost any amount on his training, the skilled workman, and so on.

The question of education and training depends naturally upon the purpose of such training, and what is necessary for, say, a foreman or draughtsman differs considerably from that necessary for a works manager, chief designer, or research specialist. Then again there are many men who, although skilled in their own lines, do not wish to take positions of higher responsibility, and, in passing, a tribute should be paid to these men on whom industry relies to such a high degree for their ability and perseverance in constantly turning out a good day's work. Whilst education and training for these men is of a type somewhat different from that of the higher executives, nevertheless it is equally essential.

In my opinion the ideal training for the young man who wishes to rise to a position of responsibility in engineering is first of all to obtain a good school education, and before leaving school to pass such examination, be it the school-leaving examination, matriculation, or equivalent, as will exempt him from the entrance examination to a university. The general knowledge so gained will be valuable, and incidentally he will then avoid the necessity of having to resume after he has commenced work the study of school subjects which is necessary in order to obtain entrance to the various professional technical institutions.

The next step in my recommended ideal training is to enter the shops of a good engineering works for 2 or preferably 3 years. This need not necessarily be an electrical works; in fact I consider that mechanical work is the best basis for electrical engineering, but there should be opportunities of varied experience and avoidance of long periods attending to repetition machines.

This practical training is valuable in many ways—it instils a realization of the practical aspect of design and construction, and, even more important, it gives a young man actual knowledge of labour conditions, a knowledge which is valuable but unfortunately not always present in those holding higher executive positions.

Following this workshop training, a university or equivalent course in engineering can be appreciated to a much higher degree than otherwise, and at the end of this course the staff of the college will usually be able to place their students who have made good, in some position where they will obtain further experience. After this it is a case of taking whatever opportunity arises but, even after the workshop and university course, training must still go on, by the reading of technical literature and association with other engineers. It is in this latter respect that this and similar institutions are so valuable,

and the engineer who does not take advantage of them is unfair not only to himself but to his colleagues.

The theoretical training should be as wide as possible, and in my opinion the great advantage of a university engineering course is that the study of engineering only commences seriously when the student has obtained a knowledge of the general principles of physics, chemistry, and mechanics. I do not for a moment suggest that an advanced knowledge of these subjects is necessary for the engineer—in fact the time spent on studying them to an advanced degree might better be spent on engineering subjects—but I do say very definitely that the engineer who has a reasonable knowledge of physics, chemistry, and mechanics, is more likely to deal with engineering problems with a wide vision. He will be able to consider the basic principles and not be a "rule of thumb" man applying formulae the basis of which he does not know, and which, therefore, he may use in cases where they are quite inapplicable.

Similarly, the engineering student should not specialize too rigorously. Whilst he should avoid wasting his energies over too wide a range he should at least have a good general mechanical knowledge no matter what branch of engineering he intends to follow, and even for the mechanical or electrical engineer a knowledge of the design of structures is very useful.

It will probably be argued that the foregoing procedure is open only to the privileged few, even though scholarships make it easier for the keen student. With this I fully agree, and would emphasize that I prefaced my remarks by stating that this was the "ideal."

In Plymouth, for example, to obtain experience in mechanical engineering is far from easy, but I have been more and more impressed by the fact that a good man will rise despite the limitations of his early training. For example, switchboard work, wiring installation work, and the preparation of mains sketches, all form a basis which may lead to higher positions for men who are prepared to study, but I must emphasize that in these cases promotion is usually later in life than in the case of the "ideal" training.

I would, however, state that in my opinion there is little prospect for advancement in engineering for the man who has not had 2 or 3 years' practical experience of some description. The "paper" or "arm-chair" engineer is not able to visualize the problems with which he is confronted, and at the risk of sounding discouraging I would suggest to the man whose experience has been purely of a clerical or office character that he would be well advised not to turn to engineering unless he is prepared to spend 2 or 3 years on practical work. Similarly, the man with only a college training, no matter how good it may be, is of little use in the engineering world without the practical side.

My conclusions in both these cases are based on experience in dealing with men both with and without practical training, although this experience has made it clear that it would be unwise to dogmatize as to the exact nature of the practical training. The main thing is that the engineer must have worked with his hands, mixed with workmen, and had experience of the conditions under which work is carried out and plant is operated.

If a preliminary practical training of this type can be followed by a university course in engineering, it is all to the good, and in this case my previous remarks would apply.

There are, however, a number of cases where a university or other day engineering course is not possible, and in such cases the only alternative for the young man who wishes to master the theoretical side is evening class work. This is by no means easy, but I suggest that the results justify the hard work entailed.

Here, again, I would suggest also that specialization should not begin too early. If the preliminary education has not been up to the standard of the entrance examinations for the various professional institutions, it is highly desirable that such ground should be covered first of all. A year may then well be spent on physics, chemistry, and mechanics, after which courses in engineering will be mastered more readily.

The theoretical side is, however, not the only one that needs cultivating. Visits to factories and constructional works are extremely valuable, and I personally owe much to the visits in which I was able to join while I was a student on the North-East Coast.

For all grades of engineers a knowledge of the English language is highly desirable, in fact I would say essential. I know that I am repeating what has been said previously countless times, but my experience has impressed on me the importance of an engineer being able to write a connected report or letter relating to his work, and particularly the cultivation of the ability of giving direct replies to questions. This may sound absurd, but I have been surprised at the number of engineers who, when asked a straightforward question relating to their work, give a rambling reply from which the questioner can cull the information required only with difficulty, and at the expense of a considerable waste of time.

It may seem unnecessary to stress the importance of good team work, but my experience leads me to emphasize that this should be included as part of the training of the engineer, for we all know of competent engineers whose abilities are not utilized to the full because they are not prepared to work smoothly with others. The other man may not know as much as you about your own particular work, but it is highly probable that he knows considerably more than you about his particular work, and it is the combination of the two that is necessary. Team work is necessary not only amongst engineers, but between them and their non-technical colleagues.

I should like also to emphasize the importance of three other qualities for engineers, namely accuracy, reliability, and initiative, and I personally consider that it would be advantageous if more attention were given to them in technical college training.

The importance of accuracy should be self-evident, but I have more than once come in contact with young engineers who have imagined that, providing that methods of calculation were right, accuracy was of secondary importance. It should be obvious that in commercial life this is far from true, and every attention during training should therefore be given to developing the facility of quick and accurate calculation work.

Similarly, it may seem unnecessary to stress the importance of reliability, but here again my experience has shown that this quality is not always present. An

assistant who can always be relied on to carry out, without further reminder, all the instructions given to him is in possession of one quality that will mark him out as at least worthy of consideration for promotion, as nothing is more unsatisfactory to those in positions of responsibility than to find it necessary to give constant reminders to those under them in order to get work carried out.

With regard to the quality of initiative, some little explanation may perhaps be helpful. By initiative I refer to the determination not to be thwarted by difficulties. This means that if a problem seems insolvable from one line of attack one should start again by approaching it from a different point of view. I think that this can best be illustrated by some advice which was given to me in my student days. This was as follows: If you are given a problem to work out on certain lines, and you find that you cannot do it as suggested, do not go to your chief, asking what you should do. Rather say that you cannot solve the problem on the lines indicated, but that you suggest alternative solutions and wish to know if one of these is acceptable. Your chief is probably busy and has not had the time to give full consideration to the problem, and if, therefore, you go to him with a blank, he has to tackle the problem himself from the beginning. If, on the other hand, you submit alternative methods of dealing with the problem you have saved considerable time, and even if your suggestion is not finally adopted it will assist in arriving at the final decision. Incidentally you will have shown that you possess the initiative that in due course should help towards your own promotion.

These remarks have been very brief, but I hope that they may draw attention to the various aspects of engineering training. What I particularly want to emphasize is that practical training and theoretical training, whilst both very necessary, are not enough in themselves. Association with other engineers is just as necessary, and this association should not be limited to engineers engaged in one's own specialized branch. The supply engineer has much to learn from the manufacturing engineer, the heavy-current engineer from the light-current engineer, the research engineer from the selling engineer, and so on. One of the best mediums for this association is The Institution, its Centres, and its Sub-Centres, which make provision for a wide range, from Students to full Members.

I appeal to the Students to make full use of the Sub-Centre, to attend the meetings, and not to be afraid to join in the discussions, which give a good opportunity to practise public speaking. I do not suggest that irrelevant rambling discourses should be indulged in, but Students' contributions to the discussions which are either sincere requests for information, or which put forward concisely some experience or information not previously brought forward, are always helpful.

I apologize, if apology be necessary, for addressing my remarks mainly to the Students and younger engineers, but I trust that some of the suggestions I have made, which are based on a varied experience, may be helpful to them.

In conclusion I should again like to emphasize that The Institution is of untold value to younger engineers, for whose benefit this Sub-Centre has very largely been formed. It is up to them to continue to support it, as the future of the Sub-Centre depends upon the support of individual members.

With regard to the older members, their attendance and participation will be to the benefit not only of themselves and their colleagues of riper experience, but also to the Students and younger engineers by whom the industry will be led in years to come.

HAMPSHIRE SUB-CENTRE: CHAIRMAN'S ADDRESS

By W. S. LONSDALE, Member.*

"SOME ELECTRICALLY-PROPELLED VESSELS"

(*Address delivered at* SOUTHAMPTON, 12*th October*, 1938.)

I have taken this as the subject for my Address chiefly because we all live near and hold our meetings alternately at the two seaports of Southampton and Portsmouth and are thus in close touch with sea-going vessels. As I have been interested for many years now in the applications of electric power for propelling and steering ships, I thought it might also be of interest to the members if I were to say something about the design, construction, and layout, of some recent electric propulsion equipments.

The company with which I am connected has within the past few years designed and supplied the engines and electrical machinery for a number of interesting electrically-propelled vessels. I propose only to refer in particular to some locally-built electric tugs and an electric ferry on which Diesel engines driving generators provide the electric power for the motors propelling the vessel.

HISTORY

Some of the members will probably be surprised to learn that records show that the first electrically-propelled boat was built about 100 years ago. This was in 1839 when Jacobi was successful in propelling a boat on the River Neva at about 2 miles per hour.

We then have to wait for about 40 years, when in 1882 an iron boat was built to run on the River Thames. This boat was capable of carrying 12 people and was driven by a 3-h.p. electric motor; a speed of about 8 m.p.h. was attained.

We now come to 1903, when the Russians were the first to employ heavy-oil engines on board ship and also made use of Diesel-electric propulsion with two vessels built for service on the Volga and operated by Nobel Brothers Petroleum Products Co.

Interest in this method of propulsion then seemed to lapse until about the year 1919, when owners started to give serious thought to electrically-propelled ships. Since that time its popularity has risen and fallen until the present time, when there are very definite indications of a rise to favour again.

A reference to Lloyd's List shows that at the present time there are about 110 vessels coming under the classification of electric propulsion, totalling over 600 000 tons.

In addition to these there are probably considerably over 100 smaller craft such as tugs, ferries, and dredgers, which employ this form of drive.

Of this large number of Diesel-electric vessels which are in operation to-day very few, as will be seen from the list given in Table 1, are operating in British waters.

Table 1

DIESEL-ELECTRIC VESSELS OPERATING IN BRITISH ISLES

Class	Name	Installed brake horse-power
Tugs	Aclam Cross	600
	Lectro	720
	Framfield	530
	Sir Montague	400
	Duchess of Abercorn	1 000
	Robertsbridge	530
Ferries	Queen Margaret	370
	Robert the Bruce	370
	I.O.W. Medina River	50
	Clyde Navigation Trust	500
Passenger vessels	Lochfyne	1 600
	Loch Nevis	1 300
	Talisman	1 600
Special service	Vigia	300
	Patricia	1 710
Admiralty	Adventure	6 000

It is difficult to understand why this should be so, as there are a great many special services for which a strong argument may be put forward for Diesel-electric propulsion.

APPLICATIONS

If we put aside the possibility of Diesel-electric competing with the direct Diesel drive for normal cargo- and passenger-carrying vessels, it is interesting to consider the following broad types of craft for which electric propulsion has very definite advantages:—

(A) Vessels requiring excessive manœuvring and full torque at low propeller speeds, e.g. tugs and tenders.

(B) Vessels which require special transmission between the prime mover and propulsion gear, e.g. paddle vessels and chain ferries.

(C) Vessels for special duties, such as dredgers, fire-floats, ice-breakers, lightships, naval vessels, and others requiring low cruising speeds, etc.

ADVANTAGES

Some of the advantages of the Diesel-electric drive for vessels are:—

(1) Propeller speed designed to suit conditions.

* The English Electric Company, Ltd.

(2) Direct wheel-house control.

(3) Reliability and low maintenance costs, due to engines operating under ideal conditions.

(4) Equipment safeguarded against overload, minimizing breakdowns in service.

(5) Reduced operating staff.

SHIP- AND BARGE-HANDLING TUGS

The Diesel-electric tug owes its existence to the ability of electric transmission to couple a medium- or high-speed Diesel engine, or a number of these sets, to a large low-speed propeller, and to the rapid manœuvring which can be obtained by this method of power transmission without stressing the engines.

Table 2 gives a list of the salient features of some British Diesel-electric tugs which have been put in commission during the past 5 years, and a comparison is shown with some American tugs.

DIESEL-ELECTRIC TUG "FRAMFIELD"

This tug was built by Messrs. John I. Thornycroft & Co., Ltd., at Southampton. It was put into service in March, 1935, and has been in almost continuous service since that date.

Table 2 gives the leading particulars of this tug, from which it will be observed that the Diesel engines, electric generators, and the whole of the electrical equipment, have been designed and constructed by the same company, thus ensuring complete co-ordination in the design of the machinery as a whole.

General Arrangement.

As will be indicated later, the machinery is situated amidships and a notable feature of the vessel is the absence of a funnel, the exhausts being carried up through the tops of the engine-room ventilators.

Propelling and Auxiliary Machinery.

The propelling machinery of the "Framfield" consists of two sets of Diesel-driven electric generators which supply current to the propulsion motor.

The Diesel engines are of the vertical, totally-enclosed, 4-stroke cycle type, with mechanical injection. Each has 6 cylinders (10 in. dia. × 12 in. stroke) and each is capable of a continuous output of 265 b.h.p. at 530 r.p.m.

The engines are of monobloc construction and are pressure-lubricated throughout. Special provision is made for washing out the cylinder jackets with water at high pressure, and large inspection doors are fitted to the cylinder heads. The camshaft is chain-driven and provided with extra-large bearings. The air inlet and exhaust valves are housed in removable cages, so that the valves can be removed and ground in without disturbing the cylinder head.

The fuel and oil filters are of the dual type, so that they can be cleaned while the engines are running.

The main generators are direct-coupled to their respective engines, and each has an output of 168 kW at 350 volts (d.c.). These generators are of the marine type with rotatable magnet frames.

The main generator shaft is extended to carry the armature of an overhung type auxiliary generator which

Table 2

DIESEL-ELECTRIC TUGS

	British						American
Name	"Acklam Cross"	"Lectro"	"Framfield"	"Sir Montague"	"Duchess of Abercorn"	"Robertsbridge"	"Van Dyke," I to IV
Type	Ship-handling	Barge-towing	Barge-towing	Barge-towing	Tender & salvage	Barge-towing	Barge-handling
Owners	Robinson & Crosthwaite	Union Lighterage Co.	Thames S.T. & L., Co.	Erith & Dartford L. Co.	Belfast Harbour Co.	Thames S.T. & L., Co.	Atlantic Refining Co.
Date in service	August, 1933	October, 1933	March, 1935	April, 1936	November, 1936	January, 1938	1924
Dimensions	90′(bp)×22′×11′6″	86′×22′×11′6″	77′6″×19′6″×10′3″	70′×17′6″×8′6″	115′×27′×12′6″	77′6″×19′6″×10′3″	87′×21′×9′6″
Builders	Hall, Russell, & Co.	Hy. Robb & Co.	J. I. Thornycroft	Smith's Dock Co.	Harland & Wolff	J. I. Thornycroft	—
Engine builders	Brotherhood Ricardo	Mirrlees	English Electric	Davey Paxman	Harland & Wolff	English Electric	Ingersoll-Rand
B.H.P., total	600	720	530	440	1 200	530	450
Speed, r.p.m.	900	300	530	650	550	530	257
Electrical equipment	G.E.C.	B.T.H.	English Electric	G.E.C.	Harland & Wolff	English Electric	American G.E.C.
S.H.P.	500	580	400	350	1 000	400	375
Propulsion motor speed, r.p.m.	90/100	100/130	100/140	120/150	—	115/150	107/140

furnishes independent excitation for the sets, each having an output of 25 kW at 110 volts. Both the main and auxiliary generators are protected by canopies to prevent condensed moisture from the engine room falling on the machines, and the machines are self-ventilated and specially insulated for marine service.

the main controller, and access doors, are all interlocked by Castell keys to prevent access to the back of the board when it is " alive," and also to prevent excitation being broken when on load. Indicating lamps are also fitted to show which main generator and auxiliary generator are on circuit, and earth-indicating lamps are fitted for each circuit. There is also a warning lamp for excess current.

Table 3

DIESEL-ELECTRIC TUG " FRAMFIELD "

Summary of Towing Trials with Two Different Propellers

	Test No. 1 1 130 tons' tow 100-r.p.m. propeller					*Test No. 2* 1 112 tons' tow 130-r.p.m. propeller				
	Shaft horse-power	Speed	Pull	Knots	Tow-rope horse-power	Shaft horse-power	Speed	Pull	Knots	Tow-rope horse-power
		r.p.m.	tons				r.p.m.	tons		
With tide ..	373	104	4·75	4·675	—	399	128	5·25	4·38	—
Over tide ..	376	105	4·80	4·516	—	393	127	5·10	4·23	—
Mean	374·5	104·5	4·77	4·59	151	396	127·5	5·175	4·305	153

The propulsion motor is of the double-armature, forced-ventilated type and is capable of developing 400 s.h.p. at any speed between 100 and 140 r.p.m. The magnet frames of this motor can be rotated in their cradles in the same manner as the generators, to simplify inspection.

The main bearings of the generators and the propulsion motor incorporate a special method of disc lubrication.

The main control board is of the " dead front " type, being completely enclosed.

The control of the propulsion equipment is carried out on the Ward–Leonard principle, in which the generators and motor are electrically coupled in series. The output and direction of rotation of the propulsion motor are controlled by varying the strength and direction of the excitation of the main generators. This method of control gives smooth acceleration at all speeds, together with simple and economical operation.

A special feature of the design of the control equipment is that it is impossible to overload the engines. After the engines have been started and run up to speed, and the control taken over on the bridge, no further adjustments are necessary in the engine room, and the system requires no auxiliary motor-generator set, contactors, or delicate apparatus.

Table 4

DIESEL-ELECTRIC TUG " FRAMFIELD "

Summary of Standing-Pull Trials with Two Different Propellers

With 100-r.p.m. propeller						With 130-r.p.m. propeller					
Trial held 27th February, 1935, at Southampton Trial conditions:— 150 ft. of tow-rope was used; the draught of water was not taken, but a considerable amount of mud was stirred up						Trial held 2nd April, 1935, at Millwall Dock Trial conditions:— 180 ft. of tow-rope was used; the draught of water was 21 ft.					
No. of engines	Shaft horse-power	Speed	Pull	Shaft horse-power per ton pull	Brake horse-power per ton pull	No. of engines	Shaft horse-power	Speed	Pull	Shaft horse-power per ton pull	Brake horse-power per ton pull
		r.p.m.	tons					r.p.m.	tons		
2	385	98	6·3	61	71	2	380	116	7·1	53·6	62·5
1	195	75	3·0	65	76	2	417	118	7·125	58·4	68

The tow-rope horse-power was nil in each case.

The various controls are interlocked in order to prevent incorrect operation, each control being clearly marked to indicate its particular function.

Either engine-room or direct bridge control can be employed, the change-over switch being located on this main panel, and the switch is provided with a lock to prevent accidental movement. The excitation switches,

Provision is made to enable the tug to operate with

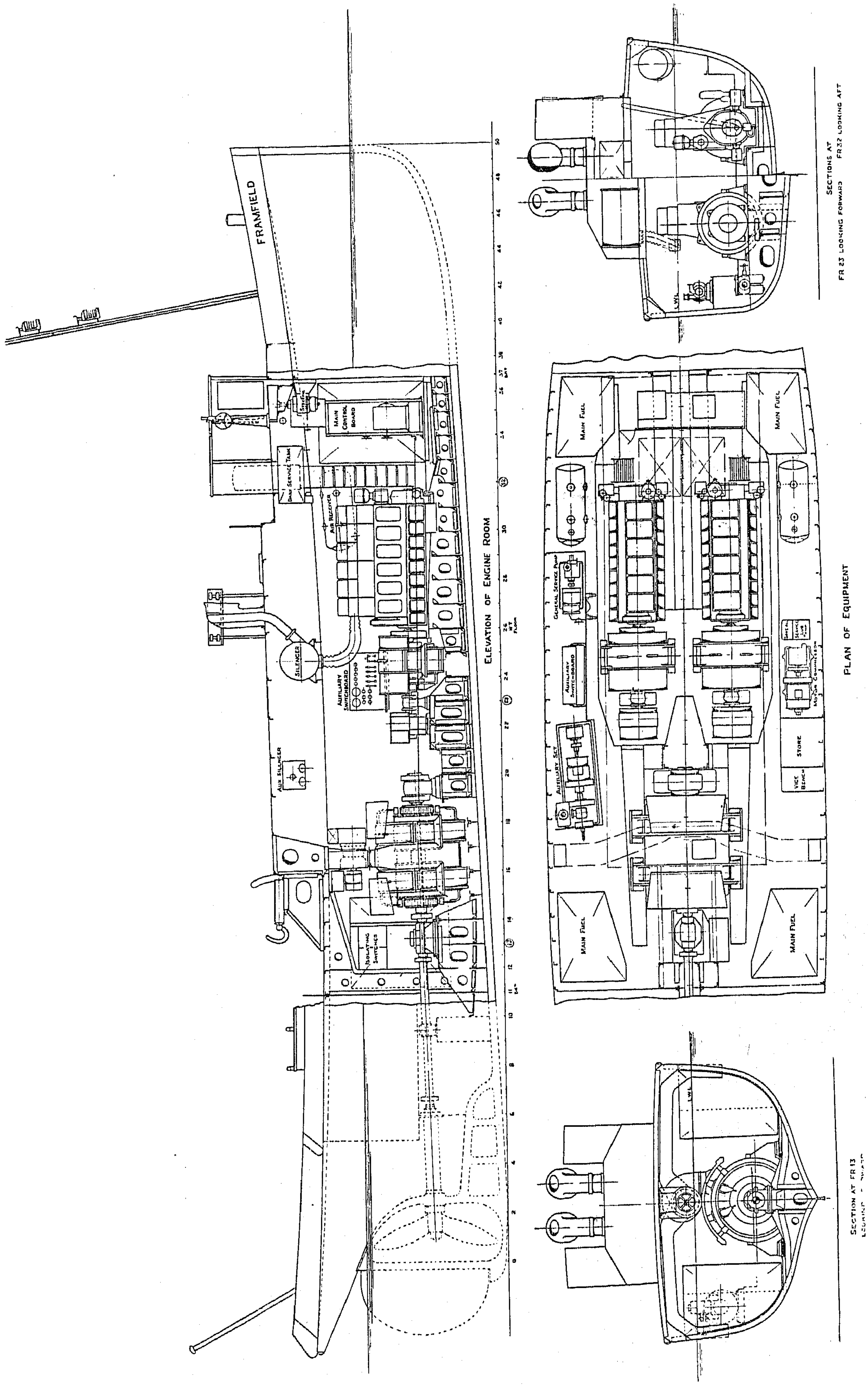


Fig. 1.—Sections showing the disposition of machinery and control gear of the Diesel-electric tug "Framfield."

either one or two engines running, and thus one engine set can be cut out of service without shutting down the complete power plant. It is also possible to run at half power with either half of the propulsion motor out of service.

The stand-by generator and compressor comprise a 5-kW, 110-volt d.c. generator direct-coupled to a 10-b.h.p. auxiliary oil engine which acts as a stand-by set and provides the power for general services when the main generators are not running.

The shaft at the commutator end of the generator is also extended to carry a clutch, through which an air compressor can be driven for charging the starting-air bottles for the main engines.

The stand-by generator control and main feeder panel is equipped with change-over switches, thus enabling the power supply to be taken from either of the auxiliary generators driven by the main engines or from the small stand-by set.

Table 5

DIESEL-ELECTRIC TUG "FRAMFIELD"

Summary of Speed Trials, Tug Running Free

With Two Engines

Run	Engine speed	Propeller speed	Input brake horse-power	Time	Knots
	r.p.m.	r.p.m.		min. sec.	
1	530	119	410	6–13	9·651
2	530	119	425	6–2	9·945
3	530	123	440	6–5½	9·849
4	530	122	434	5–55½	10·126

Mean of mean speeds = 9·893 knots = 11·2 m.p.h.
Mean h.p. input to propulsion motor = 437.
Mean s.h.p. (approximate) = 400.

With One Engine

Run	Engine speed	Propeller speed	Input brake horse-power	Time	Knots
	r.p.m.	r.p.m.		min. sec.	
1	530	94		6–55	8·675
2	530	94		7–37	7·877

Mean speed = 8·276 knots = 9·55 m.p.h.
Approximate motor input = 185 h.p.

Direct-acting electric and hand steering-gear is provided. A feature of this gear is that the control is all mechanical.

Fig. 1 shows the arrangement of the machinery in the tug. Particularly worthy of note is the symmetry and simplicity of the layout, giving easy access.

Table 3 gives a summary of the towing trials with two different propellers. As will be noted, the propellers were designed to run at 100 and 130 r.p.m. respectively under heavy towing conditions, and, as far as possible, the conditions of trial for each propeller, both as regards tow load and the state of the river, were identical. It will be noted that the results distinctly favour the slower-running propeller, the mean speed when towing being nearly 0·3 knot higher.

Table 4 shows a summary of standing-pull trials with the same two propellers. These dock tests, it will be observed, are in favour of the 130-r.p.m. propeller, but the results cannot be compared, as a short length of rope was used and the water in which the Southampton tests were carried out with the 100 r.p.m. propeller was shallow.

It might be mentioned, in passing, that it requires approximately the same pull on a tow hook to move 6 fully-loaded Thames swim barges with an aggregate of 1 600 tons at 3½ knots as it does to tow, say, a 40 000-ton (gross) liner at 3 knots.

Table 5 gives a summary of speed trials carried out on the "Framfield" in Southampton water with the tug running free. Six runs were made on the measured mile, 4 with 2 engines in operation and 2 with one engine only. On the manœuvring trials, the time elapsing from "full speed ahead" to "stop" was only 26 seconds. From "full speed astern" to "stop" the time was 22 seconds. From the propeller turning at 120 r.p.m. ahead and the vessel under full way, to the propeller starting to turn astern, required only 5 seconds. These figures demonstrate the ease and flexibility of the control equipment, all operations being carried out from the bridge during the trials.

DIESEL-ELECTRIC TUG "ROBERTSBRIDGE"

This tug is a sister ship to the "Framfield" and was built by the same firm.

The only visible difference in the appearance of this tug and that of the "Framfield" is the addition of a short funnel which was fitted at the owners' request. As a result of 2 years' experience with the "Framfield" certain modifications in the design of the "Robertsbridge" are of interest.

Propulsion Motor.

Whereas the "Framfield" is fitted with a double-armature motor weighing about 16 tons, the "Robertsbridge" is fitted with a single-armature motor weighing only 10½ tons (both including thrust block).

While the double-armature motor virtually consists of two separate machines and thus provides an additional safeguard against breakdown, since one half only may be used in an emergency it was found that the extra weight and expense was hardly justified under the particular conditions of service. The reliability of this particular motor has been 100 %, and indeed there are many motors of a similar type which have been running for 25 years or so on much more strenuous duties in steel-rolling mills.

The lower weight and dimensions of the single-armature motor has enabled the stern lines of the new tug to be fined to give a better run to the propeller.

Fig. 2 shows the arrangements of the machinery in the "Robertsbridge," from which will be seen how much space is saved by adopting the single-armature propelling motor.

Ventilation of Motor and Engine Room.

An opportunity was also taken from the results of the "Framfield" to improve the ventilation of the motor

and engine room. In the "Framfield" the motor is ventilated with air taken via trunks from the cool sides of the engine room in contact with the water. This system, however, is not altogether satisfactory, since the air in the engine room is merely re-circulated and, in hot weather, conditions in the engine room were found to be not very good. On the "Robertsbridge," therefore, a new system is employed whereby the ventilating air for with the engine-room skylights closed, thus making the bridge extremely quiet.

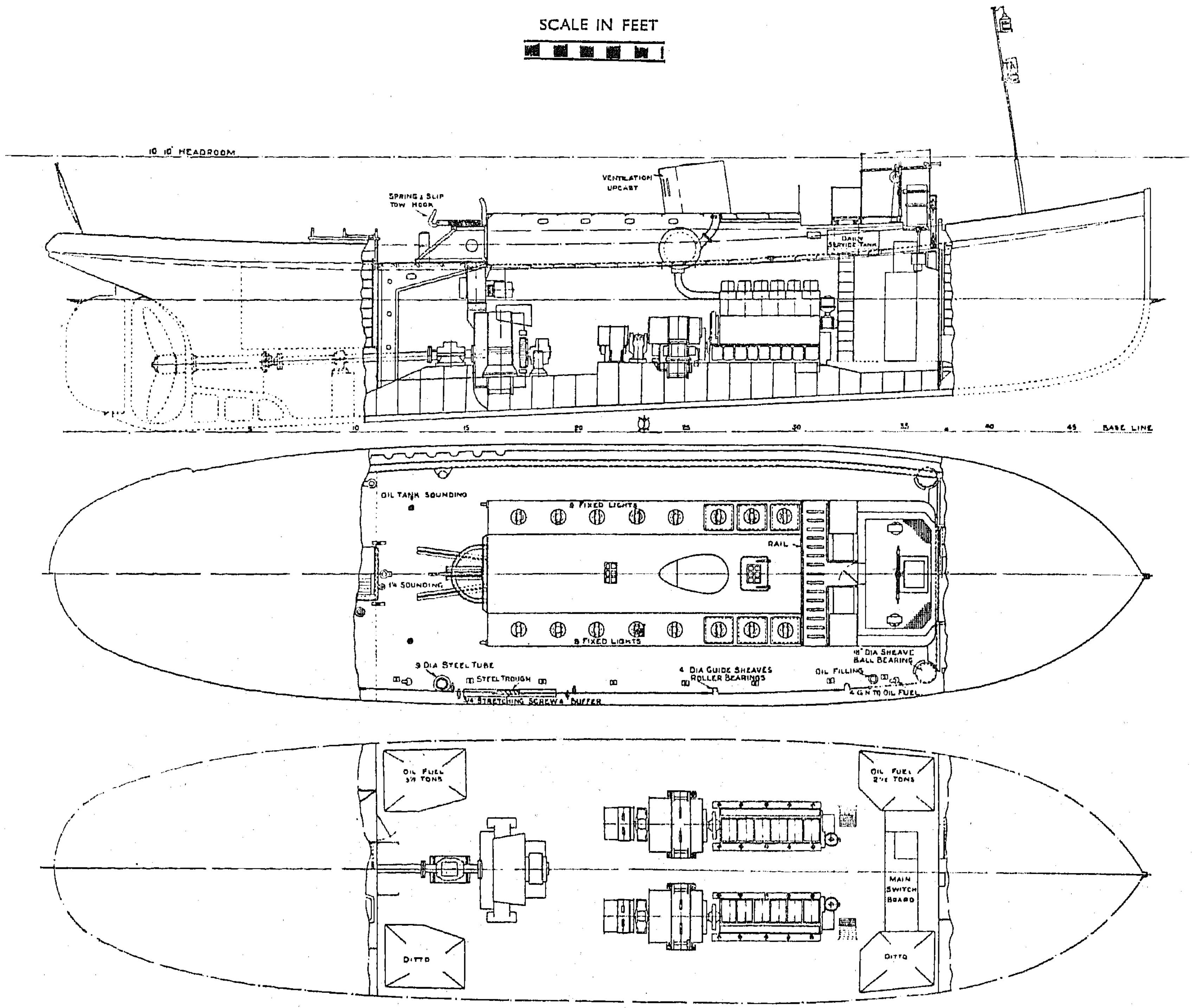


Fig. 2.—General arrangement of Diesel-electric river tug "Robertsbridge."

Length	OA	83 feet	Breadth	MLD	19 feet 6 inches
Length	BP	77 feet 6 inches	Depth		10 feet $4\frac{1}{2}$ inches

the motor is taken through a special screened opening underneath the towing table and between the two table supports. This position is well sheltered from spray and dirt, and the air from this screened opening is then drawn into the fan ventilating the motor, from which the air issues in a forward direction. Part of this air is then consumed by the Diesel engines, while the balance is expelled through the rear portion of the funnel, being assisted by the natural extractor action of the funnel. With this arrangement it is possible to run at all times

COWES DIESEL-ELECTRIC CHAIN FERRY

A very interesting application of electric propulsion to an electric ferry is to be found on the Medina River. It was put into service between East and West Cowes in August, 1936. The width of the river at Cowes is about 150 yards, and the tide is at times quite strong. This ferry runs on chains, and as there are two large works situated on either bank of the river, and as the ferry is the only means of transport for the workmen, the duty is extremely severe.

An interesting and unique feature of the machinery is that a battery is used in conjunction with small Diesel generating sets to supply the propulsion power. When the original steam ferries were running, difficulties were experienced at low tide when carrying heavy traffic,

owing to the ferry sometimes grounding and becoming fast on the mud. This condition has never arisen in connection with the electric drive, as the electric motor is able to develop a considerable excess torque over full load, and this enables the ferry to be moved under the worst conditions.

The service is such that during the busy part of the day there is a wait at each side of approximately 3 minutes for off and on loading, followed by approximately 1 minute crossing. Over 200 trips are made per day, and after careful investigation it was considered inadvisable to fit direct-drive engines which would require very frequent stopping and starting, with resulting heavy wear and constant attention.

On the other hand, if a plain Diesel-electric drive had been adopted and the engines allowed to idle at each side, a considerable loss of fuel and lubricating oil would have resulted. Another point to be borne in mind is that while a maximum power of about 60 b.h.p. is necessary on occasions to start the ferry moving, this load only persists for a few seconds, and in any event the ferry tends to

Table 6

Cowes Diesel-electric Chain Ferry

Service Record

Date in service	26 August, 1936
Hours' service to April, 1937 ..	4 016
Engine running hours	4 138
Hours run on battery alone (after equalizing charges)	4 (112 trips)
Normal daily hours and number of trips	18 hours; 216 trips
Maximum daily hours and number of trips	20 hours; 222 trips
Number of trips to April, 1937 ..	50 000 (approx.)
Fuel and lub. oil consumption	3 990 gals. fuel; 4 gals. lub. oil/week
Crew	2 deck hands 1 engineer

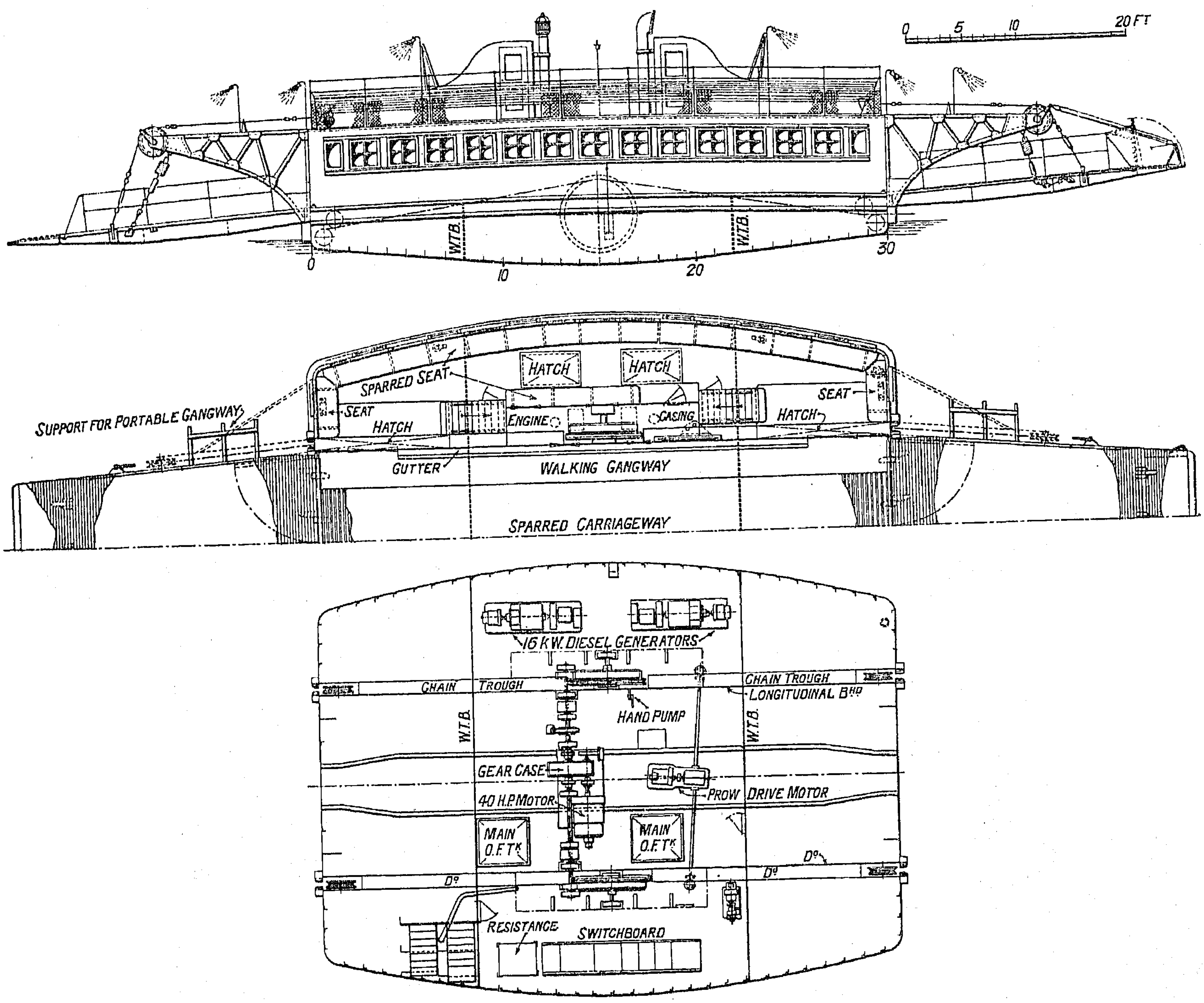


Fig. 3.—General arrangement of Diesel-electric chain ferry.

drive itself directly sufficient chain has passed over the wheels.

The readings taken during a normal run when carrying passengers correspond to a discharge output of about 8 000 ampere-sec. and an input (including "idling" time) of 13 000 ampere-sec.

Over the full working of the ferry the system is self-adjusting, and once the correct generator voltage has been set the equipment requires no further adjustment. It has only been found necessary in practice to arrange for equalizing charges at about fortnightly intervals. Only one generating set is in use at a time, the other acting as a stand-by.

Table 6 gives the service record. From particulars furnished for 8 months, as a comparison the old steam ferries used in an equivalent period 123 tons of coal, showing a direct saving in this period of £160 on fuel alone, despite the fact that the new ferry runs a larger number of trips per day.

Fig. 3 shows the general arrangement of this Diesel electric chain ferry.

The machinery consists of the following main items:—

Two 27-b.h.p., 1 200-r.p.m. Diesel engines each coupled to:—
Two 15-kW, 110/140-volt propulsion generators.
Two 2-kW, 110-volt auxiliary generators.
One 226-Ah lead-acid battery.
One 40-b.h.p. (normal), 500-r.p.m. propulsion motor.
One 10-b.h.p., 1 000-r.p.m. prow-lifting motor.

In emergency the ferry can be operated either from the battery alone, or from the two generating sets alone working in parallel. The auxiliary generators, which are overhung on the same shaft as the main generators, supply power for lights and excitation. The prow-lifting motor and service pumps take power from the main circuit.

The complete machinery is stowed below deck, despite the fact that there is very little head-room, and thus practically the whole area of the pontoon is available for passengers and vehicles.

Although this new ferry is of the same dimensions as the old steam ferry it has been found possible to carry about 150 more passengers, owing to the absence of casings required for engines on one side and the boiler on the other.

Direct control of the propulsion from the deck is fitted at either end, the operating control working in conjunction with time-operated contactor gear so that automatic acceleration is arranged for, and the raising and lowering of the prow at either end is done by push-button control in the driver's cab.

Although the use of the battery and twin generating sets necessitated some rather complicated automatic control gear with interlocking devices, it is interesting to record that the ferry has been operated from the start by the drivers who used to operate the steam ferries. These drivers have no electrical knowledge, yet no difficulty has been experienced and no shut-down has occurred in service.

The owners' comments on the operation of this bridge are "A decided improvement, always ready, faster, more economical, and very much cleaner."

CONCLUSION

It is only within the past few years that electricity for the propulsion of ships has commenced to make headway, but unfortunately this is only true chiefly in the case of foreign ships where foreign ship-owners continue to show their confidence in electric drive. British owners and builders do not appear as yet to have fully appreciated the merits of the system. Last month (September) the Hamburg-Amerika liner "Patria," the largest Diesel-electric ship in the world, was put into regular service between German ports, Southampton, the West Indies, and the West Coast of South America. It is inconceivable that the business men who own this ship would have adopted the electric drive without first of all having thoroughly investigated the possibilities of alternative systems of propulsion which are available.

The "Patria" is propelled by two 7 500-b.h.p., 3-phase, 3 300-volt synchronous motors.

The power is provided by 6 Diesel-driven alternators, each of 2 140 kVA normal capacity. The normal speed is 17 knots and a maximum speed of 19 knots can be obtained for short periods.

The main advantages anticipated by the owners for this ship are that she can be operated at maximum efficiency over a wide range of speeds by cutting out one or more of the main generators as service conditions require, leaving the others to run at their rated, and therefore most economical, outputs.

ACKNOWLEDGMENTS

I wish to take this opportunity of particularly thanking my colleague Mr. G. T. Shoosmith, M.A., for his permission to make considerable extracts from his paper entitled "Some Operating Results of Diesel-Electric Propulsion," which was read before the Institute of Marine Engineers in London on the 12th October, 1937, also for his permission to make use of many of the interesting tables in that paper.

Acknowledgment is also made to Mr. F. J. Mayor of the Thames Steam Tug and Lighterage Co. for permission to include the results of the tugs "Framfield" and "Robertsbridge," and also to the owners of the Cowes Electric Ferry for their permission in giving particulars of the service record.

I also wish to acknowledge the assistance given by my colleagues in preparing data and drawings for this Address.

DUNDEE SUB-CENTRE: CHAIRMAN'S ADDRESS

By G. F. MOORE, B.Sc., Associate Member.*

(*Address delivered at* DUNDEE, 13*th October*, 1938.)

Though it is the accepted practice for the chairman's address to take the form of either a review of progress in the electrical world or an epitome of his business experiences, I propose to depart from convention because I believe that more good can come from turning up new soil than by dwelling on past harvests. Accordingly I am going to take advantage of the principle that the chairman's address is not open for discussion and talk for a little while on what can be described, to use an American phrase, as the "end product" of all our efforts—"Electricity Service"—because there are few who can deny that the future of the whole electrical industry is inevitably bound up in the meaning attached to these words.

The increase that has occurred in the number of those who attend the monthly meetings of this Sub-Centre during the period it has been my pleasure to participate, effectively reflects the rapid expansion which has taken place within the electrical industry. The contemplation of its present prosperous condition may well arouse pardonable feelings of pride and satisfaction within all who are actively engaged in its many branches. The growth in the total sales of electrical energy for the country has been quicker than was anticipated; nevertheless at such times as these, when it is desirable to peer as far into the future as our conceptions will permit, we should take stock of our position, check our bearings, and make sure that the course is still set right for us to reach our objective; if not, whether some slight adjustments or corrections might well be made.

When a broad view is being taken of the trend of progress in regard to the control of the supply industry it is worth while noticing the direction the drift is taking. There is a widespread belief that it is the selling price of the unit that is mitigating against the development of the business and increase of sales. Consequently, every conceivable effort is being made, including the pending re-organization of distribution, that can be calculated to bring the price per unit to the consumer down to the lowest possible economic figure. The principle behind these efforts is, of course, highly commendable, though it is debatable whether the consequential publicity which the affairs of the industry receive does not do enormous harm. For each person who gets a grasp of the situation there are hundreds who only acquire a superficial knowledge. Their opinions are therefore ill-informed, and the prejudiced mind reacts unfavourably towards the industry. It is not for me to predict whether or not these proposals will achieve the avowed object, but it is significant that in many areas of the country to-day where the price per unit is $\frac{1}{3}$d. and less, there is not that positive advancement being made which the proposers would have us anticipate. Consequently, other reasons must be sought to give the reason why cheapness alone is not sufficient to make a pre-eminent success of the business in which we are engaged.

One sometimes feels that engineers are so occupied with the immense technical problems with which they are confronted that they need to be reminded that the stewardship of what may well prove to be the greatest of all the public services is in their hands. The demands of public service are, to my mind, like the laws of nature—inexorable. Cognizance must be taken of them. If these demands are ignored then I venture to predict that the stewardship must perforce be transferred to more willing hands. There have of recent times been examples of such action plainly visible for those who care to see, where individuals not possessing engineering qualifications have been appointed to the highest administrative posts in supply undertakings. Electrical engineers have every reason to feel proud of their achievements, for example the mammoth base-load stations and the super-voltage cables. But the community as a whole care little about these things; to them they are but the means to the end. It is the "end product" they care about, of course; the conveniences, the personal benefits, the aids to a healthier and brighter existence, that all can receive from the application of electricity to the needs of their daily lives.

It is admitted by all observers that the greatest field for expansion of this industry now lies in the sphere of domestic electrification, a sphere in which it is far more difficult to make progress than in its counterpart, industrial electrification. When dealing with the needs of industry a case for the utilization of electrical energy for a particular process can be formulated, and accepted or rejected, on purely economic grounds. Here those with whom the decision rests are, as is befitting their responsibilities and positions, generally more intelligent than the mass of the public. The case for the application of electricity for domestic requirements often needs to be presented from other angles, as all who are accustomed to dealing directly with the public readily admit. The consumption per head of population for this country is yet short of 400 units per annum and it is believed that at least a five-fold increase is ultimately attainable. If this be so then might it not be postulated that the extent to which this achievement is secured will be a measure of the electricity service which the industry has given the public?

If therefore a complete success is to be made of this stewardship—and it is vital that a success shall be made —there must be a very detailed examination of the

* Kirkcaldy Corporation Electricity Department.

problem. In its solution all the resources of human wisdom should be employed, for the result will be achieved not only by the application of engineering principles but rather by an understanding of human psychology. Psychology is a subject that few education authorities include in their engineering courses, but there is a pressing need for its inclusion to-day. The pursuit of its study lies on a road hitherto little traversed by engineers. They are concerned with the performance of articles of their own creation, created for a specific purpose and expected to yield definite predicted results. A little reflection, however, might serve to bring their aims into proper perspective, would they but remember that statutory authorities for giving an electricity supply (whence springs this great industry in which we find employment) are formed not for the purpose of seeing what percentage efficiency can be obtained from the required plant or other ancillary occupations, but primarily to serve the needs of the community.

We who know all that can be achieved for the amelioration of the lot of mankind at the touch of a switch, and have at heart the welfare of the public, have a duty to see that all are made aware of the benefits that may be received when full use is made of the service. It may seem that what is advocated should be obvious to all, that the story has been and is being told, and that the results will be forthcoming. But is this the right viewpoint? Surely the only people to whom such benefits are obvious are those few who have already availed themselves of the service. It is by studying the preferences, inhibitions, emotions, and reactions, of the community that approach can be made to this complex problem. Already other public bodies, such as the B.B.C. and the London Passenger Transport Board, are taking these factors into consideration.

There are numerous examples of the amazing results which can be achieved by the application of the fruits of a study of this nature. One readily springs to mind—the introduction by the Post Office of the "greetings telegram." This feature was adopted a short time ago and was an immediate success for it satisfied a definite public need. Now an average of 100 000 such telegrams are being delivered each week. The psychological reaction of the public to the receipt of a telegram had been critically examined. Formerly there were few people, it is said, who could open the dull yellow envelope of the ordinary telegram without a tremor of anxiety, for there were many who regarded it as a harbinger of bad news. Those whose first impulse was to send a telegram embodying felicitations were restrained from doing so by their thoughts of the recipients' first feelings. Now the gaily coloured and decorated greetings telegram envelope dispels all fears, and in preparing the mind to receive the contents enhances the substance of the words.

Another example is evident in the notable success, as indicated by the market value of the shares and the declared dividends, of those firms controlling the chain stores to be found in most towns. Undoubtedly the large volume of business and turnover has largely been achieved by the applications of the lessons to be learnt from a study of the public preference—the open display, easy access to goods, and the positioning of counters for particular selling lines.

Since constructive proposals are always more welcome than criticism, which is merely destructive, a few suggestions as to how this industry might attack this problem might not be out of place. Each section of the electrical industry—the supply undertakings, the manufacturers, and the electrical contractors—is involved. The service which is rendered is the product of the efficiencies of the sectional contributions. Where the efficiency of a unit is dependent on three variable factors, then unless each factor possesses an individual efficiency of a high order the product is rapidly diminished.

It is inevitable that under existing conditions complete harmony between the sections cannot be attained, with the result that the commendable efforts of one party are often depreciated by the remissness of one or both of the others. The manufacturers endeavour to make appliances to suit the numerous and extensive regulations of the supply undertakings, notwithstanding the fact that the units sold by the latter depend on the efficiency and cost of the appliances. The contractors, left with a wide choice as to the manner in which the appliance shall be connected for receiving its energy, possibly make an incomplete job of it. The party which is left to bear the result of the disharmony, the cost of the wasted effort, the annoyance, and the irritation, is the public. One is bound to ask how much longer this state of affairs is to be permitted to continue, and when and what action can be taken to provide a remedy.

Each section subscribes to an association—the supply undertakings to the Incorporated Municipal Electrical Association and the Incorporated Association of Electric Power Companies, the manufacturers to the British Electrical and Allied Manufacturers' Association, and the contractors to the National Register of Electrical Installation Contractors. The councils of these associations should consider whether anything is being done by their members to make the public react unfavourably to the industry and is inimical to the public convenience and interest.

Joint conferences representative of each association should be regularly convened at which the activities of each would be discussed, difficulties and anomalies liquidated, and efforts co-ordinated. The research, which is now commendably being conducted principally by the manufacturers, would be assisted by generous help from the supply undertakings and the contractors. Its value would then be greatly enhanced, because it could be so directed to produce results which would be simultaneously beneficial to the three parties and to the public.

Lastly, there would be concerted action in presenting the service to the public. The co-ordination of the publicity and advertising now separately undertaken by each section would enable a tremendous combined propaganda to be maintained.

The dominating theme of their respective and joint deliberations would be simplicity, whilst every endeavour should be made to produce logical solutions. With simplicity predominant in each section of the industry, confusion of the public mind is avoided. Subconscious habits are more easily acquired where confusion in the mind does not exist.

It should be remembered that even to-day the community regard electricity as something mysterious and

dangerous. Because of this they are afraid (especially the women) and therefore seek to avoid it wherever possible. The tendency is, as it were, to take detour round the wood rather than the short footpath through it. That these fears are very gradually being allayed is granted; nevertheless, the phobia the people have subconsciously developed prevents them from making inquiries about it in an endeavour to arrive at a simple understanding of its function as an aid and servant in their daily lives, for the ordinary human being has a high natural inquisitive and acquisitive instinct. Consequently there exists in the public mind a great deal of ignorance and confusion, which, unfortunately, we engineers have not helped to diminish. This is exemplified in the vexed question of earthing. One asks oneself whether the public have really been assisted to understand the importance of this precaution. Some supply undertakings are letting out on hire and selling on hire-purchase appliances on which, to relieve them of responsibility, they are fixing a transfer warning the consumer that the appliance must not be used under certain circumstances unless it is connected in a particular way. This results in a great deal of the good which the hire of the appliance is meant to achieve being vitiated.

On the other hand, the public are using the so-called all-insulated appliances and tumbler switches in the belief that therein lies safety, while we know that such is not the case. It is to be regretted that the industry did not early recognize the importance of joint action on this question to ensure that the metal work of every appliance, fitting, and installation, was arranged from the outset for positive earthing.

It is recognized that the Wiring Regulations Committee of this Institution has done most valuable work in an endeavour to untie the tangled knot into which the industry finds itself with regard to electrical installations and appliances, and tribute must also be paid to the Apparatus Committee of the Incorporated Municipal Electrical Association and to the British Standards Institution. But were the work of these bodies and others connected with the industry co-ordinated and the decisions at which they arrive as a result of their deliberations intimated to the joint meetings of the section councils these could then agree to adopt and enforce their adoption by all the industry.

Such a fusion of interests is already being prepared by the gas industry, to control which there is about to be born the British Gas Federation. Many of us are aware of the keen competition that already has to be met from our rivals. With a unification of their forces one can expect an intensification of the attack.

There is, however, much work which, in my opinion, can be done meanwhile to induce the public to believe subconsciously in electricity service. Since it is the domestic sphere to which we are looking for expansion, the attention must be directed to the women folk. But the woman of to-morrow is the girl of to-day, and young girls of 14 years of age are being taught domestic science and cooking at school. Also there are evening continuation classes in domestic economy and cookery for older girls. In nearly every school the teaching of these scholars is being done by the aid of gas appliances. The children are being taught how to clean and use a gas cooker, thus they grow up with every chance of acquiring a gas complex. Those who have made a study of child training are aware how deep-rooted are the habits acquired in tender years, and how difficult they are to eradicate in after life. The harm which is being done to the industry is incalculable. Strenuous efforts should therefore be made to get suitable electrical appliances installed in the schoolrooms. There is little chance of inducing the education authorities, already hard-pressed financially, to bear the cost of substitution. The equipment should be offered free to both schools and training colleges, and no difficulty need be experienced in arranging for a tariff with a running charge equal to that of the domestic two-part tariff.

Apart from the question of the training of young persons there are numerous women's associations and guilds in every town. These bodies exist for the advancement of feminine interest and welfare and should be approached with the offer to provide for their members simple interesting talks, lectures, and demonstrations, centred around the various aspects of electricity service.

Much of the advertising and publicity which is being done to-day by the industry lacks feminine appeal. Probably more than 90 % of the service lies, as it were, in femine territory, and it is to them that it should be presented. Simple informative articles on electrical installations, appliances, and their uses, should appear regularly in the numerous weekly and monthly women's periodicals. Surely we can count the dissemination of such information of equal importance to that of gardening or motoring.

A further point which I should like to make while dealing with feminine interests concerns supply undertakings. It will be conceded that the initial inquiry for a supply or the hire and hire-purchase of appliances is usually made by the housewife. The subsequent procedure for giving effect to the request should be as simple as possible, and every endeavour should be made to create an atmosphere whereby the applicant is made to feel that she is about to take advantage of a service to which she has every right, instead of making her feel that a concession is being bestowed upon her, by imposing a multitude of conditions to which she must first conform. In order that she can take interest in the economy of the service, consideration should also be given to whether electricity meters which could be read by all should not in future be supplied. The clock-train type of register is notoriously difficult to read by the lay person, and meters fitted with cyclometer registers, on which the indices of decimals of a unit are obscured, would help considerably.

Turning now to another aspect, it is disturbing to reflect on the number of houses which are being built by local authorities with State assistance in which it is customary to find gas wash-boilers and gas cookers fitted. The chances of the tenants who are to occupy such houses substituting electrical appliances are very remote, and consequently a great load is being lost for a number of years. The decision that these houses shall be so equipped usually rests with a committee of laymen. Without wishing to be disrespectful it can be said that they are on safer ground when discussing the merits of gas appliances than electrical ones, because they have

been associated with the former during the greater part of their lives. It is to these gentlemen, then, that most careful attention should be given. No pains should be spared in exploring every avenue of approach to induce them to witness conveniently arranged demonstrations and to make themselves familiar with the advantages and economies that ensue. Where circumstances permit offers to install the appliances in their homes should be made, in order that their wives may give them the benefit of their experience. There is big business to be won in this direction, for a single motion disposes of hundreds of these appliances. It will not come by waiting till later years reveal the mistake. It has to be fought for and won by strenuous efforts now or the opportunity will be lost.

I have endeavoured to indicate to some extent the future policy which would appear to be most profitable to pursue. It is a policy in which all can take an active part by helping to simplify and standardize the complex variety of appliances and installations from which the public make their choice.

My final remarks are in the nature of an appeal. There are over 400 000 people employed in the electrical industry, 80 000 of whom are engaged in the supply undertakings. I wonder how many, whose only means of livelihood arises from the industry, are giving their practical support to the cause by using electricity for their household needs. There are many still using gas for cooking who are prepared to stand up and advocate all the advantages to be derived from the use of electrical appliances. It is for each to ask himself whether or not it is his duty to avail himself of the service and, by example rather than precept, induce others with whom he comes in contact to do likewise.

NORTHERN IRELAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By F. JOHNSTON, Member.*

"ELECTRICAL AND OTHER THINGS TO COME"

(*Address delivered at* BELFAST, 18th *October*, 1938.)

By trying to visualize the present trend of progress in the various branches of electrical development, I mean to make an attempt to forecast where it is likely to lead us in the near future. Just as one can take a graph representing actual experimental results and extend it to show what is likely to happen if the experiment were to be carried on to a further stage, so can we try to form a mental picture of the future from the facts of the past. Progress in the form of a graph may take the shape of a series of peaks and valleys, a line through which, however, is always in an upward direction. This resultant curve may resemble that connecting magnetization and ampere-turns, showing a rapid preliminary rise and then a slow bending-over until it is almost, but not quite, horizontal, indicating that progress with time has, after a rapid increase, become almost stationary. If this is so it shows a dangerous state of affairs, for at any moment the curve may take a downward trend, and, as in the case of the discharge curve of a battery, take a sudden steep drop, indicating collapse and ultimate exhaustion. It then ceases to be a curve of progress and becomes one of retrogression. The graphs which I am trying to visualize, however, have all a steady upward trend in this country, and in what follows I shall try to picture the direction in which they seem to me to be leading us.

LIGHTING

In our future homes I visualize an almost perfectly cool light, the source of which is entirely hidden from direct view with little, if any, shadow, and differing in quality to no appreciable extent from daylight from a clear northern sky. This light will be automatically switched on in sections, controlled by photo-electric cells or their equivalent. Thus the artificial light will increase imperceptibly as the natural daylight decreases. Except in bedrooms this light will be kept on continuously throughout the dark hours in our homes, in public buildings, shops, and streets. The future would seem to bristle with difficulties for the evil-doers! Our roads will be illuminated by continuous troughs of light, similarly controlled and also with the actual source of light hidden from view. The roads themselves will be dead-white or cream, and there will of course be no horse traffic or dirty exhausts to contaminate them. Similarly, the railway tracks will be illuminated along the whole route, and the country on each side will be as visible as in the daytime. Headlights on cars will at first be retained for emergency use and will then disappear entirely. Our present forms of insanitary wall papers with their garish colour effects will disappear and the desired decoration will be obtained by mixing, with the ordinary daylight illumination, lamps of the primary colours capable of being faded out or strengthened to give the exact shade required for the time of year, weather conditions, or the occasion. This light will be reflected on to walls, ceilings, and columns, sprayed with metallic silver coatings. Thus an infinite variety of colour effects will be obtained to suit individual tastes at the moment, warm rich tones predominating in the winter months and cool tones during the hot spells.

HEATING

Isolated heaters will have no part in our future schemes of heating. They will be replaced by low-temperature electric panels imbedded in or forming part of the walls, ceilings, and floors. This heating will be controlled by reliable thermostats with temperature adjustments in each room. Ultra-violet rays will be introduced with this heating, automatically controlled to supply the deficiencies from the sun.

Glass, terrazzo, or vitreous tiles, laid on reinforced concrete or metal, will take the place of the unhygienic dust- and microbe-collecting wooden floor-boards and carpets of our day. Easily removable mats of synthetic rubber or other material will be interwoven with heating wires thermostatically controlled, to give the necessary softness of tread and low-temperature radiation.

VENTILATION

All systems of ventilation in the home and elsewhere will be associated with air-conditioning. The air will be filtered to free it from dust, disinfected to free it from disease germs, heated in winter and cooled in summer to keep it at an equable temperature, and treated to keep the moisture content constant under all conditions of the outside atmosphere. It might be thought that this would have the effect of making the human system more susceptible to disease when going outside, but it should be remembered that if air-conditioning became general and not merely confined to a few buildings, the atmosphere would tend to improve as a whole and that this, together with a better system of sanitation, the elimination of coal fires, and generally more healthy conditions of living, would ultimately eliminate disease germs. Our atmosphere would become like that of Switzerland and similar mountainous regions. Air-conditioning will also be extended to all trains and road vehicles and to all factories and workshops.

CLEANSING

The present insanitary custom of collecting refuse and garbage of all descriptions in dustbins will give place to removal direct to the sewers. Powerful electrically-driven centrifugal compressor exhausters in the basement, in conjunction with electrically-driven disintegrators and digestors, will be connected by incorrodible pipes to each

* Harland and Wolff, Ltd.

compartment, terminating in floor plates into which all dust and waste products of all description will disappear. Portable connections will also be provided on this system by means of which periodical cleaning-up will be effectively and quickly carried out. All dirt will thus be taken with the sewage to properly-designed sewage works, where it will be converted into fertilizers and/or gas for running power plants.

TRANSPORT

The position of transport, which is becoming rapidly more and more difficult, especially in our large cities, calls for drastic remedies. This will be greatly assisted in the future by the air services. I suggest that all main traffic between London and the large centres such as Glasgow, Edinburgh, Manchester, Liverpool, Birmingham, Southampton, Bristol, Belfast, and Dublin, will be by aeroplanes carrying on an average about 50 persons with their luggage. Such planes would have a wing spread of about 160 ft., a gross weight of some 30 tons, and would be equipped with 4 engines, each of some 1 000 horse-power, and have an average speed of, say, 250 m.p.h. They would thus reach Liverpool in something under an hour and Glasgow in $1\frac{1}{2}$ hours, while the journey to New York would take about 12 hours' actual flying. For the Atlantic flight, machines carrying 100 passengers with a maximum non-stop flight of 5 000 miles and a paying load capacity of 11 tons would carry on a quick and regular service. These planes would be fitted with all the latest systems of electric heating, ventilation, and air-conditioning, as on the land. The crew would consist of some 16 persons. Lightly-built Diesel-electric coaches would convey some 50 passengers at a time by wide highways to a super-aerodrome outside London, and similarly in other large towns, and there be guided into specially constructed frameworks built underneath the planes, where they would be automatically locked in position, and the planes, already idling over, would then take off for their various destinations. Releasing gear, operated from the pilot's cabin, would enable the undercarriage to be dropped in an emergency, and a combination of parachute and balloon, filled with gas automatically generated by chemical means, would enable them to float safely to land.

For heavy goods the existing railways, electrified and speeded up, might be retained, but for relatively light goods and relatively short journeys Diesel-electric coaches, built to the same standard as those taking passengers to the aerodromes, would be provided for on wide arterial one-way roads.

In the towns themselves the traffic would be confined strictly to silent battery-driven vehicles which, with one-way traffic and no horns, would eliminate the noise nuisance. Batteries would have a greater storage power than can now be obtained, and charging stations would take the place of the petrol stations.

ELECTRIC SUPPLY

The grid will survive but will be enormously increased in size, and the overhead system will be replaced by an underground one. The overhead wires will go, firstly as a safeguard against enemy aerial attack, secondly as a safeguard against the ever-increasing aeroplane services in peace time, thirdly for the same reasons that our telephone wires are now being put underground, and lastly for purely aesthetic reasons.

The generating stations of the future will either be equipped with rotary oil engines or will have large stand-by oil engines for dealing with the peaks. The fuel will either be obtained from coal (in the form of oil) or will be in the form of gas obtained from large sewage schemes such as are now in operation at Birmingham and Mogden.

As regards tariffs, the maximum-demand system will have disappeared. This system has already ceased to be fair, in that the peak loads of the factories, the only consumers to whom it is practical to apply this tariff, do not necessarily synchronize with that of the grid. This is brought about by the fact that the domestic load, for which the maximum-demand tariff is impracticable, is growing at a much greater rate than the factory load. This increase in domestic load is primarily in the direction of cooking and heating, so that the lighting peaks, which used to occur in the evening, are now tending to occur in the early morning and at midday. The result is a gradual flattening-out of the load curve, and the peaks of the future will mostly be caused by cooking and heating.

For this reason I foresee that the tariff of the future will be a simple two-part one, a fixed annual charge based on the kilowatt capacity of the supply cables, to cover interest and depreciation on the capital outlay, and a unit charge to cover running costs. This will apply both to factories and to domestic supply.

AGRICULTURE

It is becoming more and more necessary to make our country self-contained so far as food is concerned, and until we can obtain a united world, which is far beyond the period I am trying to visualize, this ideal is an important one. There will therefore be tremendous opportunities for electricity, not only in the heating of the soil and irradiation but also in producing the sun's rays whilst the sun is hidden. In this way we shall be able, with the addition of an extensive system of fertilizing, very materially to increase the amount of foodstuffs which we grow. In round figures, we now have some 5 million acres in corn crops and $2\frac{1}{2}$ million acres in green crops under cultivation in Great Britain and Northern Ireland, say $7\frac{1}{2}$ million acres in all. With this we produce some 24 million tons of foodstuff per annum, ranging from about 1 ton per acre for corn crops to some 20 tons per acre for mangolds. To be self-supporting we should have to grow about 4 times this amount. This can only be accomplished by the methods referred to. Our farms of the future will therefore be covered with networks of cables carrying a voltage of some 100 000, some form of mercury-vapour or neon lamps, and soil-heating cables controlled by thermostats. Water will also be stored up in large underground reservoirs during the wet periods and sprayed over the land by electric pumps during the times of drought. The same system would also be utilized for spraying crops with chemical manures and chemical preparations for protection against all forms of blight.

HOUSING

The subject of housing gives perhaps the greatest scope for our imagination. When our hairy ancestors forsook the trees for the caves they continued to live in some sort of comfort for a considerable number of years. Ulti-

mately, however, they also increased to such an extent that the natural caves became congested, and as they had not the technique of building new caves or of enlarging the natural caves they had to develop a system of mud huts, skin tents, log cabins, and so on, until at last we had the stone and brick dwellings and finally the ferro-concrete skyscrapers which disfigure the landscape in New York and in cities nearer home. Now, if one of our forbears had had the ingenuity of starting to enlarge his cave, developments might easily have proceeded earthwards instead of skywards, and then how much better off we might have been! With our present technique of excavating, ventilating, heating, drainage, and air-conditioning, we could live comfortably and safely underground, whilst retaining the surface of the earth for recreation and pleasure.

We are not likely in the future to get any preliminary warning of the approach of hostile aeroplanes, as, apart from the development of silent engines, the aeroplanes of the future will be able to soar to such heights as to approach their destination quite silently with their engines stopped.

Now, to revert to underground dwellings will seem to most of us to be a retrograde step, but it is difficult to foresee a satisfactory alternative until such time as the human race, as a whole, is willing to settle its differences in a more intelligent manner than that adopted by their cave-dwelling ancestors. Consequently, I visualize that all our sleeping quarters in the future will be below ground, with only our sun parlours, living-rooms, and recreation rooms, above ground. Our workshops and offices, especially those on important Government work, our public buildings, and generating stations, will all be underground. When one remembers that in a large passenger liner we are almost entirely dependent, in a large proportion of the ship, on artificial light and on ventilation from above, it can be appreciated that there would be no real engineering difficulties in carrying out this idea. Apart from the advantages in time of war, our underground quarters would be easier to keep at an equable temperature in all weather conditions and would be very much quieter.

In recent years, we have been hearing a great deal about the housing question, block dwellings, slum clearances, housing estates, garden cities, and satellite towns, but progress in this direction is very slow, and something much more drastic will be required to meet our future requirements as regards congestion and safety. Much could be done by spreading dwellings over larger areas, but as long as modern conditions prevail and human nature remains what it is we shall have to face the fact that people must congregate together, both for business and the social purposes of life. When we consider that every fifth person in the British Isles is a Londoner, it can be realized what a very difficult problem the housing is in that city, and that nothing short of some very drastic change can ever be successful in meeting the requirements of modern conditions of peace and war. We already have our underground railways, and it is no very great stretch of the imagination to visualize our large cities extending in a downward direction instead of in encircling rings, as at present, until there is a regular network of streets, houses, and shops, 20 or 30 ft. below the road-levels, electrically lit, heated, ventilated, and air-conditioned. Incidentally, our stairways will all disappear and their place will be taken by electrically-operated escalators, with push-button control in our homes and running continuously in our public buildings.

EDUCATION

A considerably higher general standard of education will be attained, and to this end wireless and television will come to our aid. A purely educational side of the British Broadcasting Corporation will be developed, from which nothing but the best educational facilities will be available. Our schoolrooms will be provided with screens in every classroom for wireless television, by which medium the very best of the nation's teachers and lecturers, each in their specialized subjects, will be seen and heard. The same will apply to music and the arts, for not only will sound and colour be faithfully reproduced but depth will also be given to the pictures by means of stereoscopic devices. By this means the great masters in all walks of life will be brought within the reach of all. Those who are too delicate, too far away from educational centres, or otherwise incapacitated from joining classes, will be able to obtain the same facilities in their own homes. Local teachers will, of course, still be required in the schools to keep order, arrange the classes, and give individual assistance.

POLITICS

By the same means we shall be able to see and hear, quietly in our own homes, the advocates of both sides in a political controversy. Political opponents will be able to give their views in the quiet of the studio, and after the elections we shall be able to see and hear our representatives in the House and in committee and thus be in a position to form a much better idea of their usefulness, or otherwise, than is possible at present.

THEATRES, ENTERTAINMENT, AND SPORT

The technique of the wireless and television in colours with stereoscopic effects will be such that all the best plays, concerts, sporting events, and entertainments of all kinds, will be available to all in such quality that going out to see them will be a thing of the past. Instead of having to sit through something which we do not find interesting, we shall be able to switch from one entertainment to another until we find something to our liking.

TELEGRAPHS AND TELEPHONE SERVICES

Television will be coupled up with the telephone service, and telewriters and teleprinters with the telegraph, and both services will be available in all homes and offices. In the business offices, heads of departments will be able to see and hear any of the staff under their control and to witness any operation being carried out in any part of the works. Messages and sketches will be teletyped and telewritten between the departments as well as to the outside world.

CONCLUSION

Some of the forecasts which I have made may seem fantastic and in any case much too expensive to carry out. My answer is that the technique is already known and by the time they are carried out we shall have satisfied ourselves that money is only something we manufacture to represent men and goods, and have awakened to the fact that we have plenty of both and can produce more.

SHEFFIELD SUB-CENTRE: CHAIRMAN'S ADDRESS

By H. W. KEFFORD, Member.*

"TRENDS OF DEVELOPMENT AFFECTING POWER INSTALLATIONS"

(*Address delivered at* SHEFFIELD, 19*th October*, 1938.)

Electricity now plays such an important part in every department of life that it is recognized by the State and by the public as an essential service, without which domestic life and industrial and business activities would be seriously dislocated. Perhaps the most striking features of the electrical industry at the present day are the accelerating intensity of domestic applications, a marked expansion of the use of electricity for industrial purposes, and the almost universal tendency for power supplies to be bought rather than generated privately.

As a result, we see continual extension of public generating and distributing systems, and healthy activity of electrical manufacturing, measured both by the volume of its production for home and export requirements and by its technical progress, this progress being the result to a very great extent of the close co-operation of users of electrical equipment.

This stage of maturity involves greater responsibilities for the electrical engineer in charge of an important installation, and, correspondingly, his standing has risen to a level at least equal to that attained in the other branches of engineering with which he has to co-operate. His decisions and his work are governed always by regard for the essentials of human safety and continuity of service, which have to be fulfilled with what he judges to be the highest economy. These factors of safety and continuity with economy will be obtained in varying degree dependent upon the planning of the layout, the selection and installation of the apparatus, and its operation and maintenance.

As already mentioned, safety of workpeople is the first consideration, and any doubt as to its importance is removed by the necessity of complying with the Factory Act and the Regulations made under it. The State has usually concerned itself with industrial operations in normal times only for the purpose of safeguarding the welfare of the workpeople. To-day, however, much attention has to be given to A.R.P., not altogether from the safety point of view alone, but largely also with the object of ensuring that the whole production system may be carried on with as little disturbance as possible under emergency conditions.

Some safety precautions in electrical installations are well established. Enclosure of live metal, adequate passages, proper earthing, double exits from enclosed spaces, safe rupturing capacity, interlocking and isolation, and many others.

One of the most frequent types of accident in all classes of works is shock from some part of the circuit of portable apparatus, and especially from flexible leads and apparatus connected to them. Portable transformers to supply circuits at a safe voltage were first employed in connection with portable lamps used by men working in boilers, but there is a strong case for the more general use of these extra-low-voltage "safety" units, either fixed or portable, for the supply to portable leads used for other purposes. Such a practice would dispose of this type of risk. The use of low voltages for the lighting of machine tools is becoming standard practice, on account both of its safety and of the greater strength of the lamps. It also simplifies the wiring if a double-wound transformer is connected across two phases of the power supply used for driving the machine.

The use of flexible conductors in workshops should be avoided as much as possible, even for fixed lighting points, as they are particularly liable to misuse and deterioration. Generally speaking, it is desirable to eliminate all material of a combustible nature; in many cases a risk is created by quantities of main cabling with exposed surfaces of highly inflammable material that can be ignited quite easily.

The urgency for reducing the risk of shock or fire in every part of an installation is shown by the following statement which occurred in a recent speech of an insurance authority: "Fires of electrical origin are becoming more numerous. Although sometimes outbreaks from unknown causes are attributed to electrical faults without definite evidence, there is reason to believe that an increasing fire wastage occurs from this factor. So many installations of a type falling far short of present standards date back 25 or 30 years, and their efficiency and safety unless periodically overhauled must now be open to question."

The Factories Act, 1937, specifically requires that generators, motors, rotary convertors, prime movers, and flywheels, shall have every part securely fenced. There has been a tendency to assume that this is something quite new which renders former design and installation practice inadequate; but this seems an exaggerated view, because under the former Act the same protection was required in practice, although it was not specified so precisely. Generally speaking, the protection hitherto afforded by designs of machines or guards has not proved inefficient for preventing accidents. An important requirement of the new Act is the provision, in every room or place where work is carried on, of devices or appliances for promptly cutting off power. This precaution has for long been general practice, but where it has been omitted the necessary "stop" push-buttons must be provided.

Having touched briefly on the first essential of safety, I shall now draw attention to some matters that influence

* The English Electric Company, Ltd.

the continuity and economy of electrical operation. It should be noted, however, that the two requirements are to an appreciable extent complementary. A personal accident may interrupt working either directly or indirectly, and, conversely, breakdown of a piece of equipment may cause human damage or may lead to accident indirectly, as by failure of lighting. One result of the consideration that has to be given to A.R.P. is the possibility of installing emergency Diesel-engine generating plant for maintaining essential services such as lighting, pumping, ventilation, and signalling. Their compactness and ability to start up rapidly by automatic control, if desired, renders this type of plant valuable for use in circumstances where the normal supply might be interrupted; and they can easily be installed in a well-protected house.

In the present stage of development, economic distribution of power does not guarantee 100 % continuity of service without qualification, although the average outage in this country is very low.

The enormous increase in the size of the generating and distribution systems is in itself the cause of greater vulnerability, owing to the possibility of lightning damaging an overhead line or of failure of a main transformer or switching centre. The first safeguard against cessation of supply is duplication of the feeding line, and therefore it is always desirable that the service to a large works should be either by two feeders from the distributing centre, or by two legs of a ring system. A.R.P. adds further weight to the desirability of this arrangement and, in fact, points to the added necessity of bringing duplicate feeds to widely separated points in a large works area, as near to load centres as practicable. From the works engineer's standpoint the elements of an e.h.t. distribution in his area obtained in this manner tend to cheapen and simplify the internal distribution system.

Perhaps the most important problem created by the increasing scale of generation, distribution, and utilization, is that of rupturing capacity of circuit-breaking devices.

A great deal of progress has been made in investigating circuit-breaking phenomena in the several testing stations in this and other countries, and improved designs of arc-controlled switchgear have been evolved capable of consistent performance under specified conditions. At the same time it should be realized that these important researches are still being continued not only in the direction of discovering simpler, safer, and more effective circuit-breaking devices, but also with the object of placing on a rational basis the assessment of what the actual short-circuit characteristics can be at any point on a network; for these characteristics may conceivably differ from those produced by test station equipment. Similar remarks apply also to protective fuses, the merits of which deserve some notice, considering how much their use has extended with the development of the high-rupturing-capacity cartridge type. The survival of fusible cut-outs for short-circuit protection is due no doubt to their simplicity, compactness, and cheapness. The consistent performance and selective action of a modern high-rupturing-capacity fuse obtained by simple means in a small space are remarkable when compared with automatic switchgear of equivalent rupturing capacity. It is certain that these advantages will lead to further improvements based upon the experimental work that is being carried on.

The problems of rupturing capacity to be considered by the works engineer may take various forms. If it is practicable, as it is in some types of factory, to subdivide the works distribution system into a number of isolated sections, each fed from its own step-down transformer, the short-circuit capacity required in the low-voltage switchgear will be greatly reduced. In other cases the problem may be that existing switchgear is rendered inadequate because the works generating capacity has been largely increased, or a bulk supply has been brought in to supplement it. In these cases current-limiting reactors are extremely useful.

Thought for future expansion will often be well repaid and future difficulties will be avoided if main switchgear is liberally specified as regards both rupturing capacity and busbar capacity, and space is allowed for additional units.

Many of the refinements and safeguards now introduced into the switch-houses of public power stations in order to ensure continuity of service are hardly justifiable in works installations except those of the largest size; but, nevertheless, the underlying principles should always be borne in mind. To-day it is the endeavour to raise to a higher index the factor of safety due to sectionalizing and duplication of busbars, by wider physical segregation of the duplicated elements into fireproof chambers, and to carry automatic protection into the hitherto unprotected zone of the busbars themselves. More practical for the works engineer are the elimination of fire risks by adequate venting, the rendering innocuous of spilled oil, and particularly the fireproofing of cables and the sealing of openings in floors. The remote control of oil circuit-breakers, especially of units rated at 150 000 kVA and over, is a desirable feature. If they are operated infrequently, spring-closing is suitable and cheaper than solenoid operation. The extra cost of remote-operated switchgear liable to heavy currents, or associated with sequence or other interlocks, is compensated for by greater safety and reduced maintenance.

The inherent flexibility, efficiency, and simplicity, which have made the static transformer the key to large transmission and distribution systems, have contributed very much also to the extended use of electric power for industrial purposes. As examples of simple transformer action, we have the induction furnace and the roll heater, whilst a transformer of some kind is the basis of arc and resistance welders in numerous forms, the arc furnace, the resistor furnace, the rivet heater, the induction regulator, and many other appliances. The transformer and the reactor have given us a ready means of limiting the current flow under short-circuit conditions, and when increased reactance introduced difficulty with voltage regulation, that difficulty was neutralized by the development of automatic tap-changing. The reliability of transformers is exceptionally high, and there seem to be only two directions in which improvement is possible, the elimination of oil and the attainment of a higher factor of safety against lightning surges. Although comparatively few cases of fire occur, progress is being made towards the production of fireproof units. The

quite old scheme of using air-cooling has been revived in conjunction with a high degree of fireproofness in the windings, and non-inflammable liquids of the Pyranol type are being used quite widely in America. It is desirable to install oil-immersed transformers out of doors, or in a separate fireproof chamber, and to render any emission of oil as harmless as possible by installing each unit within a brick or concrete pit or parapet above a sump filled with gravel. In some circumstances it is an advantage to have cable boxes so designed that they can be disconnected from the transformer winding for the removal of the unit, without the necessity of unmaking the cable joints to the boxes.

Investigation into the circuit phenomena resulting from lightning, and into the best way of guarding against resulting damage, is now engaging the close attention of manufacturers, and as progress is made this source of interruption of supply will be diminished or eliminated.

It appears that in other countries situated in large continental areas clouds are usually high and lightning seldom strikes to earth, although storms may be violent and frequent. In England, however, the storm clouds are lower, as a rule, with the result that direct flashes to earth often occur.

To protect transformers against direct strokes would be extremely difficult, but considerable progress has been made towards rendering them immune from any but the most severe conditions. Modification of the line insulation to promote spillage and duplication of the earth wire tends to safeguard the terminal equipment, whilst developments in the transformer itself include more scientific grading of the coil insulation, and more appropriate arrangement of the connections and the insulation between them.

Reactors can be a useful and efficient solution of the problem of providing additional reactance and limiting the short-circuit current. Modern designs of oil-immersed reactors of the magnetic-shielded or ironclad types are as effective as, and more compact and far safer than, the older ironless air-cooled design, and units of these kinds are now in use for inter-busbar or feeder protection on many of the largest systems, including the 132 kV grid. They are also used in works for bringing the short-circuit current within the safe working limit of existing switchgear, and for supplementing the reactance of transformers of old design. As a rule the voltage-drop due to the insertion of a reactor is not of serious amount.

A type of transformer apparatus that has a wide field of usefulness in workshops of many kinds is welding equipment. Some of these make use of the resistance principle, as in spot, butt, or flash welding, also the continuous resistance welding of seams, whilst arc welding has its own extensive range of utility.

Arc-welding equipments now in operation are suitable for welding currents up to as much as 1 000 amperes, and two or more such equipments can be used in parallel for joining steel plates up to $3\frac{1}{2}$ in. thickness with a single run of weld. The alternating-current process has been proved to be entirely satisfactory for the great majority of purposes, and it has the advantages of being easily regulated and operated from compact static equipment requiring a negligible amount of attention.

One of the greatest difficulties with which an engineer has to contend in an industrial district is that of dirt. He is obliged to spend money in a continuous attempt to remove it from his running machinery, but in the end it damages his expensive converting plant, motors, and control apparatus.

The damage caused by dirt in the electrical circuits is serious because it may affect conduction, insulation, and ventilation. Impaired conductivity can be caused by corrosion, abrasion, or deposition of non-conducting film.

Insulation may be affected by oil and moisture and by conducting material, either on the surface or within the insulating material, with harmful effect on its chemical properties and the distribution of electrical stress; but perhaps the most harmful effect of dirt is its interference with ventilation, especially the cooling of running machinery, which leads to overheating or electrical overstressing, and finally breakdown.

There is certainly at the present time a fuller appreciation of the true economy of adequate ventilation, that is to say, cooling combined with the exclusion of dirt. This may be attributed amongst other causes to the higher costs of plant and of labour, to the use of higher voltages on alternating-current motors, and to improvements in design of the ventilating arrangements available. At the present time large machines and substations installed in iron and steel works and under similar bad atmospheric conditions are almost invariably provided with ventilation equipment for giving an ample flow of cleaned and cool air either to the individual machine frames or into the room in which they are installed. There seems to be a strong case for extending these principles to old machines and substations where ventilation is insufficient or dirt is prevalent. The design of new substations should be specially considered from this angle, and it may be found that a structure without natural lighting may be cleaner, more dust-tight, and more adaptable to A.R.P.

For low-voltage distribution in workshops armoured multi-core cable is largely used to-day in association with metalclad switchgear and fusegear. As a substitute for conduit which tends to become cumbrous and somewhat inflexible with the addition of new circuits, or alterations to old ones, a number of alternatives are now available. One is a system of rectangular steel casings with removable covers, and a flexible range of adaptors and fittings. Another which has already been widely adopted is the metal-cased busbar system. This busbar system is particularly suitable for feeding shops containing many small machine tools, the arrangement of which may perhaps be altered from time to time. The busbar casing is conveniently run overhead along the centre of the bay, and provision is made at frequent intervals so that small fuse boxes may be plugged in, from which the connection to individual machines can be made by conduit or flexible conductors. Another innovation that appears to be serviceable in special cases is a system of copper-sheathed single or multi-core conductors with insulation consisting of a refractory mineral. In this connection it is interesting to record activity in the improvement of insulating materials, more especially for the windings of motors and other apparatus, thereby increasing their durability and giving technical advantages to the designer. Enamel

and paper separately and in combination have withstood the test of extensive use, and, more recently, spun glass has been used as an alternative to the older types of insulation.

There seems to be hardly any limit to the adaptation of electric motors to drives of the most arduous and complicated character for which steam, compressed air, or water power, have been previously used. Many of these applications are made easier by the availability of reliable automatic control gear that can be installed in the most favourable position, and operated from any desired point by a push-button or a master controller. Many of the improvements in the mechanical and electrical construction of motors are well known. The insulation, jointing, and bracing, of windings has been improved, and temperature gradients have been made more uniform.

Improvements in the technique of electric condenser manufacture have placed this simple solution of power-factor improvement on an economical basis for many types of factories.

In spite of the apparent disadvantage of direct-current motors, especially when the power supply is alternating, many of the most important heavy drives still find their best solution by direct current, as for variable-speed rolling-mill drives, colliery winders, steel-works auxiliaries, and, of course, electric traction. The inherent flexibility of direct current is well demonstrated by the following examples:—

The two rolls of a two-high reversing mill can be driven ideally without any pinion housing to connect them mechanically, if each roll is coupled to its own motor and the two motor armatures are connected in series. A more recent example is the "inherent-regulation" coiler drive as applied to the coiling reels of cold-strip mills. The direct-current machines of this drive are so designed as to maintain automatically any desired constant tension in the strip, as the diameter of the coil or the mill speed varies, without the use of any external regulating apparatus. It has been found advantageous to use this equipment also in the inverse direction to apply a braking tension to the strip on the entering side, the braking energy in this case being returned to the supply system.

In conclusion it may be said that electrical engineers are in a unique position to increase the safety and productiveness of every industry, by applying to the selection, installation, and maintenance of electrical equipment, the wide experience and technical capacity which they, as a body, possess.

TEES-SIDE SUB-CENTRE: CHAIRMAN'S ADDRESS

By H. H. MULLENS, B.Sc., Associate Member.*

"SOME PROBLEMS OF THE ELECTRICITY SUPPLY INDUSTRY ARISING OUT OF EXISTING AND PROPOSED LEGISLATION"

(ABSTRACT *of Address delivered at* MIDDLESBROUGH, 19*th October*, 1938.)

I propose to give in this address a short review of the existing Acts and an analysis of the proposed legislation outlined in the McGowan Committee's Report in 1936 and the Government White Paper on Electricity Distribution—Outline of Proposals, 1937.

EXISTING LEGISLATION

Although the first legislation, viz. the Electric Lighting Act (1882), was based largely on earlier enactments dealing with the gas industry and was framed before the commencement of the supply of electricity, it was, together with its amending Act of 1888, effective and far-sighted. The titles are reminders that, although the Acts apply to the supply of electricity for all purposes, lighting was the main purpose in the minds of the legislators, and the application of electricity to power was almost unknown. There followed in 1899 the Electric Lighting (Clauses) Act containing a Schedule, the clauses of which, with any necessary modifications, are incorporated in every Special Order or Special Act authorizing the supply of electricity within an area.

Unfortunately, in these early Acts there are certain provisions which have proved to be detrimental to development, and the first of these to which I would refer is that in Section 27 of the Electric Lighting Act (1882). This conferred upon the local authority the right to purchase the undertaking or so much of it as was within their jurisdiction at the expiration of a period of 21 years from the passing of the Act confirming the undertakers' Provisional Order, or at the expiration of every subsequent period of 7 years. These periods were found, having regard to the terms of purchase, to be too short to offer an inducement to the investment of capital in electricity supply undertakings, and accordingly Section 2 of the Electricity Lighting Act (1888) substituted 42 for 21 years and 10 for 7 years.

Although the Acts so far mentioned provided for maximum prices, it was hoped that a better safeguard would be found in municipal operation, and hence the earlier legislation was framed on the basis that local authorities would become immediate or ultimate owners of electric light undertakings. Experience, however, proved that the competition of other forms of energy was the most powerful factor in reducing prices and that with electricity no complete monopoly is possible. It is of interest to note that the provision for ultimate ownership by local authorities had the effect of causing the development of a greater number of municipal undertakings in this country than abroad, where private enterprise, either alone or in conjunction with municipal authorities, was more generally employed. There is, unfortunately, the danger of this section acting as a deterrent to the investment of capital in company undertakings, a danger which increases as the time approaches when the undertaking may be compulsorily purchased.

I should like at this point to make it clear that I do not wish either here, or anywhere else in this address, to convey a preference for either private or public ownership of electricity supply undertakings. In my opinion, it would be equally unsatisfactory if undertakings owned by local authorities were subject to similar provisions for compulsory purchase.

It is remarkable that, in spite of the disastrous effect which had previously resulted from competition between other public utilities, especially amongst the railway companies, Section 1 of the Electric Lighting Act (1888) should stipulate that the granting of authority to any undertaking to supply electricity would not in any way restrict the granting of authority to the local authority or to any other company or person in the area. It is to be regretted that, as a result, competition was encouraged in the London district, with undesirable effects. However, fortunately for the provinces this was not the practice elsewhere.

I would refer to one section of the Schedule to the Electric Lighting (Clauses) Act, 1899, under which undertakers were prohibited from purchasing or acquiring an undertaking or associating themselves with a company or person supplying electrical energy under any Licence, Provisional Order, or Special Act, unless the undertakers were authorized by Parliament to do so. As a result it was, for many years, hardly ever practicable for municipal undertakings to amalgamate, and they were left to operate within boundaries determined without relation to the conditions governing the supply of electricity.

The power legislation of 1900, consisting of a number of private Acts, marked the first conception of the importance of power supplies and of supply undertakings operating over large defined areas, the main purpose of the Acts being the supply of electricity for power purposes and to other authorized undertakers in bulk. These Acts marked a departure from the previously accepted principle that all electricity undertakings not already owned by local authorities should be subject to purchase by such authorities. The anticipated benefits of these Acts were largely not achieved owing to legislative restriction. However, later, the Electricity Supply Acts of 1919 and 1922 consolidated the position of the power

* North-Eastern Electric Supply Company, Ltd.

companies in certain respects, but did not eliminate the competition to which they were subject because of dual rights of supply.

The Electric Lighting Act (1909) was important because in it appeared the first provision for Joint Committees or Boards to be set up as authorized undertakers operating under joint powers. However, the machinery set up by the Act relied upon voluntary amalgamation and applied to local authorities only and not to the co-operation between local authorities and companies. Having regard to the previous references to the effects of competition, it is of interest to note that it was not until the passing of this Act that unauthorized undertakers were prohibited from competing with statutory undertakers. In the same year important steps were taken towards the co-ordination of generation, with the passing of a private Act empowering certain companies to enter into and carry into effect agreements for the connecting and linking up of their generating stations and substations and for the interchange of electrical energy, a forerunner of what was effected much later for the whole of the country by the 1926 Act.

The electricity supply industry received a great stimulus during the years of the War, the development of the application of electric power to industry in particular being intensive. It is probable that this rapid development was responsible for attracting political interest, as instanced by the appointment of a number of committees culminating in the Electric Power Supply Committee in 1918—an interest which has been retained by one or other of the political parties up to the present time.

Following the recommendations of the Electric Power Supply Committee, a Bill was introduced in 1919 embodying far-reaching proposals, including compulsory powers for the acquisition of generating stations and main transmission lines. The Bill was, however, severely modified in its passage through Parliament, and the compulsory powers were jettisoned before the Bill was passed.

The Electricity Supply Act of 1919 established the Electricity Commissioners and provided for the formation of Joint Electricity Authorities who were empowered to acquire generating stations and main transmission lines, and also provided for the exercise by such Authorities of all or any of the powers of the authorized undertakers within the district. It laid down that no scheme should provide for the transfer to the authority of any part of an undertaking except with the consent of the owners. The truncated nature of this Act rendered necessary the Electricity Supply Act (1922), which was mainly an amending Act to the 1919 Act and contained various sections dealing with the finances of Joint Electricity Authorities. Unfortunately, as the establishment of these authorities was dependent upon the agreement of the parties concerned, the co-ordination achieved was small. In fact, the establishment of these authorities was no more successful than the voluntary formation of Joint Boards under the 1909 Act, there being at the present time only three Joint Electricity Authorities and five Joint Boards.

The Electricity Supply Act of 1926 relied upon its objects being achieved by compulsory and not, as in the last-mentioned Acts, by voluntary means, the principal objects being to suppress small-scale generation at a multiplicity of power stations and the eventual concentration of generation in a limited number of interconnected stations to be operated by owners on account of the Central Electricity Board. The problems of distribution were, however, left untouched.

The legislation since 1926 has consisted of two Acts, the Electricity Supply Act (1935) and the Electricity Supply (Meters) Act (1936). The former is of interest since it empowers the Central Electricity Board to supply electricity to authorized undertakers at special prices and on special conditions in cases where special circumstances exist, so that the undertakers will be enabled to supply to persons whose needs for electricity are of an exceptional nature. Although the special prices and conditions are subject to the existence of special circumstances, care will have to be exercised in the use of these powers in order not to conflict with one of the earliest principles of the electricity supply industry, viz. that undertakers must not show any undue preference, as laid down in the 1882 Act.

The 1936 Act, as its title implies, deals with a specialized branch of the electricity supply industry, and has no material effect upon development.

PROPOSED LEGISLATION

Even after this brief survey, it is apparent that, if quantity of legislation is the criterion, then the electricity supply industry has no reason for complaint. Unfortunately, the enactments have been piecemeal and contain much that is inconsistent. In the circumstances it is desirable, before adding to the already large volume of legislation, to consolidate the existing enactments and at the same time to remedy inconsistencies and detrimental provisions.

After the operation of the 1926 Act for more than a decade, it would appear that although the co-ordination of generation has been achieved the difficulties and problems in connection with distribution have not, in the meantime, lessened but have assumed a greater importance. The McGowan Committee on Electricity Distribution was appointed in 1935 to "bring under review the organization of the distribution of electricity in Great Britain, including the control of statutory electricity companies by other companies, to advise on methods by which improvements can be effected with a view to ensuring and expediting the standardization of systems, pressures, and methods of charge, further extending facilities (including supplies in rural areas), and reducing costs and to make recommendations." The Committee gave as its principal recommendations for reorganization:—

(i) A substantial reduction in the present number of undertakings by the substitution, where appropriate, of larger and more economic units.

(ii) The prevention of splitting up of comprehensive undertakings in consequence of the exercise of rights of purchase by individual local authorities.

(iii) The elimination of duplicate powers wherever they exist in the same area.

There is, in general, agreement that the uncertainty arising out of the possibility of compulsory purchase of a part or the whole of an undertaking at a comparatively

early date is undesirable and that this state of affairs should not be allowed to continue any longer than is absolutely necessary; also, there is little doubt from the experience of what has happened in the past, both in the electricity supply industry and other public utilities, that the duplication of powers has nothing to recommend it. However, there is a very wide and strong difference of opinion as to the first recommendation for a substantial reduction in the present number of undertakings. It is well to bear in mind that there is nothing new in the idea to reduce the number of undertakings. It was considered desirable as far back as 1909, when provision was made for the voluntary formation of Joint Boards, and later in 1919 when provision was made for the similar formation of Joint Electricity Authorities. Therefore it is reasonable to deduce that such criticism of the recommendations as there may be arises mainly because the Committee, being aware of the failure of voluntary methods in the past, have advocated compulsory measures. I would suggest that the issue, on broad lines, is whether the supply of electricity

(1) Is of national importance and so should be afforded with, as far as practicable, equal facilities for all; or

(2) Is not vital to the nation as a whole, and can consequently be afforded on "parochial" lines.

It is significant, as indicating the importance attached to the supply of electricity to all parts of the country, that the terms of reference should make special mention of the supplies in rural areas, where the use of electricity measured in quantity is so much less than elsewhere.

The Committee find on the matter of standardization of systems and voltages that it is not economic to carry out immediately a complete standardization. It does not take much consideration to appreciate that the cost of carrying out such work immediately would be a burden too great for the industry to bear. However, if due regard is had to the growth of the problem with that of the industry, the prospect of what may be the position in the future is alarming.

It is axiomatic that in any undertaking there is a natural tendency to standardize as, and when, the economies effected on spare plant and the greater ease of operation justify the same. Therefore it can safely be assumed that the greater the reduction in the number of undertakings, the greater would be the tendency to reduce the number of systems and voltages in use. To this extent the adoption of the Committee's recommendations would effect an improvement.

The Committee express the opinion that amalgamation will automatically produce both a standardization of charges and a reduction in costs, but beyond this make no suggestion of any moment to bring about either. I feel that in the matter of charges and costs I am approaching a subject which is highly controversial, but it is a matter that we have to face. Prices are, of course, controlled by the cost and value of the article, and the old argument again crops up as to whether they should be related to one or the other. We have to remember that, since the electricity supply industry is a public utility, it has a duty to perform and has not the freedom of the private trader. In the circumstances it may reasonably be argued that prices should be related as closely to costs as may be practicable. There is justification for assuming, in connection with standardization of charges, that in any undertaking the tendency would be to standardize so as to simplify accountancy, even if for no other reason. Consequently, a reduction in the number of tariffs would be brought about by a smaller number of undertakings.

The Committee recommend that rural areas should, in the proposed amalgamated undertakings, be linked with urban areas. However, in order to obtain any possible benefits arising out of diversity, rural areas should be linked to urban areas in which there is an appreciable industrial load. In this connection it is of interest to record that load curves for suburban areas, where it may be assumed there is little or no industry, are similar to load curves for rural areas.

It is argued by some that the linking of rural areas with urban areas is to the detriment of the consumers in the latter. This, however, presupposes that rural areas cannot, with rational development, be self-supporting. It is worth while recalling that in the earlier days of the supply of electricity it was considered doubtful whether it would be profitable to afford in urban areas certain supplies which have since proved to be the reverse of detrimental. It is therefore well to bear in mind that the same might apply to rural areas where the supply of electricity is yet at an early stage compared with that in the towns.

Irrespective of whichever view is held regarding the economics of supply in rural areas, consideration should be given as to whether it is desirable to have exceptionally low charges in specially favoured localities or a lower level of charges generally. Also, if the area to be operated by any of the proposed amalgamated undertakings is large and properly constituted, it is conceivable that the deficit, if any, on that part of the undertaking which is in the rural area would be sufficiently small to cause no hardship to the consumers in the urban areas.

The White Paper published in 1937, in addition to containing proposals for carrying out the recommendations of the McGowan Committee, introduces a further recommendation by proposing that the position of the Central Electricity Board should be safeguarded for as long as may be necessary by ensuring that the revenue to be received by the Board from the amalgamated undertakings should be substantially the same as that which the Board would have received had the undertakings remained unamalgamated.

However great the controversy raised by the proposed legislation, it should be recognized that unless a considerably greater measure of co-ordination than exists at present is attained, there is the possibility of complete national control of the supply of electricity. Whilst the political arguments for and against nationalization are outside the province of this Institution, it is relevant to indicate the improbability of the organization for the supply of electricity under complete national control being sufficiently flexible to meet successfully competition from other forms of energy, unless the production and sale of these are under the same complete control. Therefore, since there is no indication of all the competitors of electricity being similarly treated, it is desirable that the electricity supply industry should willingly enter into such arrangements as will attain greater co-ordination

without the accompaniment of complete national control.

Whatever may be the outcome of the recommendations of the McGowan Committee and the proposals of the White Paper, there is no doubt that a decision should be made as soon as practicable as to whether fresh legislation is to be introduced, since delay, with its accompanying uncertainty, is a serious deterrent to development.

Whilst it would be inappropriate to make any pretension to forecast what form future legislation may take, it does appear upon reflection that electricity supply has reached another stage in its development with the accompaniment of problems which, whether we like it or not, have to be faced, and which may be summarized under the following headings:—

(1) Consolidation of existing legislation.

(2) Prevention of splitting up of existing undertakings by compulsory purchase.

(3) Provisions for purchase after a prescribed period to be such as not to act as a deterrent to the investment of capital.

(4) Elimination of competition between undertakings where it still exists owing to dual rights of supply.

(5) Some form or forms of amalgamation.

(6) Amalgamated undertakings to be so constituted that the urban supplies bear a proper relation to the rural supplies.

(7) Measures for amalgamation to be compulsory.

CONCLUSION

I have endeavoured to show the trend of legislation governing the supply of electricity, and to indicate some of the directions in which existing enactments have proved unsatisfactory. In conclusion, I would leave with you the final thought of the necessity for the most careful deliberation in the framing of fresh legislation in order to ensure that, firstly, there shall be the minimum of disturbance, and secondly that the new legislation shall not be fragmentary but sufficiently comprehensive to satisfy the requirements of the public supply of electricity for a lengthy period.

WEST WALES SUB-CENTRE: CHAIRMAN'S ADDRESS

By J. E. DAWTRY, Associate Member.*

(*Address delivered at* SWANSEA, *27th October*, 1938.)

In this address I shall attempt to give a brief review of the progress made in industrial electrical engineering during the past 50 years. The earliest machines were shunt-wound d.c. machines used principally for works' lighting; they were belt-driven at low speeds and generated 100 volts. The armatures were of the "ring" type, i.e. the laminations were plain rings built up on a spider. The armature conductors were wound by hand over the top and underneath, in between the spider arms. This construction was wasteful in copper because the conductors between the spider arms served no useful purpose.

A story is told that the first motor was in use at an exhibition in Vienna in 1873. Two similar ring generators were supplied, and by accident the two machines were connected together. When the first machine was started as a generator the armature of the second machine rotated.

An improvement on this type was to bring all the conductors to the surface, resulting in the smooth-core type of armature, the conductors being held in position by means of wire bands. Both these types called for a long air-gap to give space for the conductors, with a result that there had to be a very strong and expensive field-magnet system. The field magnets consisted of two massive poles and coils mounted above the armatures. The commutators were similar to those of to-day, with the exception that the V slots were of many different shapes and sizes and frequently insulated with paper. The brushes consisted of blocks of compressed copper gauze; later an improved brush was built up with brass-foil sheets interspaced with graphite for lubrication purposes. These were the types used in works towards the end of the last century, and it is interesting to note that a "ring" type machine is still working at a local tinplate works as a motor, and a smooth-core generator was working at a local works until about 2 years ago.

In 1887 municipal and private enterprise were alive to the necessity of providing a public supply, and it would appear that lighting provided the greater part of the load. It is recorded that at the Deptford station engines of 1 500 h.p. were at work, and engines of 10 000 h.p. were being built but were not completed. It is interesting to note that at this period Ferranti, Ltd., were engine-builders.

In 1894 a description of the Manchester Corporation electricity works was given by their chief engineer, the late Mr. C. H. Wordingham. The plant consisted of six 100-i.h.p. and four 400-i.h.p. vertical compound condensing engines, steam pressure 120 lb. The generators were all d.c., six 590-ampere, 102-volt at 540 r.p.m., and four 590-ampere, 410-volt at 400 r.p.m. The generators were belt-driven by link belts, short drives, and jockey pulleys. Four motor-generator sets were in use and these were apparently used to supply a 5-wire distribution system. The earliest town mains were bare copper conductors on insulators in concrete culverts, and later rubber-insulated cables drawn into pipes were used. The connected load was 39 268 8-c.p. carbon lamps, 256 arc lamps, and 10 motors, which represents a possible total output of 1 million units per annum. As the carbon lamp was the principal load, a few notes on lamps would not be out of place.

The carbon lamp was introduced commercially in 1881, and from that time until 1903 had no serious rival, but about 1903 Welsbach produced his well-known gas mantle which no doubt caused the 8-c.p. carbon lamp to fall to second favourite. However, this advantage of gas lighting had a short life for in 1905 the metal-filament lamp having a drawn-wire tantalum filament was commercially produced. The arc lamp for large lighting units had the field to itself with no serious competitor right up to the War period. I remember the introduction of a mercury-vapour lamp about 1912, but this had a short life, as apparently vibration seriously affected it. The maintenance costs of arc lamps were very high in large works, as a gang of men were employed every day in trimming and adjusting them.

Reverting to power plants, in 1896 great headway was being made in America and on the Continent. In America the Westinghouse Co. and the General Electric Co. were manufacturing plant on a large scale, and both had their own generating plants. The Westinghouse Co. were generating 2-phase alternating current, and direct current, and the General Electric Co. 3-phase and direct current. On the Continent an extensive plant was in operation at the National Arms Factory, Liége, and Escher Wyss, Oerlikon, and Brown Boveri in Switzerland, were using water turbines as prime movers. Some of the earliest plants in this country were made by Siemens. Woolwich started in 1893 with 1 200-h.p. engine-driven d.c. generators at Middlesbrough, the Bedson Wire Co. had 600-h.p. machines, and Messrs. Dorman Long 225-h.p. sets.

In 1901 there were 30 public electricity stations with engines of 1 000 h.p. and above.

Parsons produced his first turbine-driven generator in 1884, but the turbine was known many years before this, and one known as the Hero engine dates back to 130 B.C. The first Parsons turbo-generator was a 10-h.p. direct-coupled machine running at 18 000 r.p.m. To show the very rapid growth of the turbine for electrical

* British Electrical Repairs, Ltd.

generation it need only be pointed out that the British Westinghouse Co. in 1903 were building four 5 500-kW sets for the Metropolitan District Railway. It was about this time that the Westinghouse Co. started at Trafford Park; also at this time, 19 years after the first electrical machine, there were many Parsons machines at work, including a 3 000-h.p. machine at Milan and a 1 000-kW machine running at 1 800 r.p.m. and direct-coupled to two d.c. generators at Newcastle. An interesting feature of this machine was an automatic arrangement for adjusting the brush-gear position with changes of load. The generators were apparently shunt-wound, and in those days it was the general practice to fit the brush-gear with a hand-wheel so that the power-house engineer could give it a turn now and again as the load varied. It is interesting to note that the earlier Curtis turbines were vertical. Direct-coupled d.c. turbine-driven machines were fairly common up to 1914, but are seldom, if ever, made to-day. For a d.c. job a gear reduction is fitted to bring the generator speed down to about 1 000 r.p.m.

One of the earliest engineers in connection with turbine-driven electrical machines was Dr. de Laval of Stockholm. His turbine was a single wheel running at very high speeds, 30 000 r.p.m. for 5 h.p., down to 10 000 r.p.m. at 300 h.p., which appeared to be the maximum. The generators were driven through a reduction gear, and an installation of approximately 250 h.p. was at work at a Yorkshire colliery up to a few years ago and may still be working. A double helical pinion was cut on the turbine shaft, the pinion engaged with two spur-wheels which were mounted on the armature shafts, the two generators being side by side.

An interesting feature of these turbines was the small-diameter shafts to give flexibility, a $\frac{5}{16}$ in. diameter shaft being used for 10 h.p. and $1\frac{1}{4}$ in. for 300 h.p.

In 1904, i.e. 10 years after the 102-volt and 410-volt generators, the plant at Manchester had increased to six 1 500-kW sets running at 94 r.p.m., generating 6 500 volts at 50 cycles. These sets supplied rotary-convertor substations, 500–550 volts for tramways and 410–205 volts on the 3-wire system for power and lighting. The power load had grown from 10 motors to 11 000 h.p. of motors and 11 068 h.p. of traction, and had so overtaken the lighting load that the latter was negligible in comparison.

Speaking of traction brings to mind a branch of electrical engineering which had made extremely rapid progress and, as far as tramways are concerned, appears to be making its exit as rapidly as its progress.

The overhead-line construction was not the earliest of tramway systems. A system of surface contacts made alive by underground switches, the switches being operated by a battery, was invented by Dr. Hopkinson in 1882. This type of system gave great scope for the inventor, for many different arrangements and modifications were introduced. It is recorded that a short length of tramway at Loughborough was operated on this system; Wolverhampton also had a similar system.

The conduit system so well known in London, where the live conductor is placed underground and the collector shoe passes through a slot, is one of the earliest type. This system was used along the front at Blackpool in 1884, but, as can be imagined, it proved quite unsuitable owing to sea water and sand driven on to the track.

The first overhead trolley-wire system in this country was constructed in 1891 at Leeds, and owing to its low first cost and low maintenance costs it became standard practice.

Railway electrification was taking place, the two earliest in this country being the City and South London, opened in 1890, and the Liverpool overhead. Both of these used direct current. Three-phase, 2-speed motors were first installed on the Continent by Brown Boveri, and the Simplon Tunnel Railway was fitted with 3 300-volt, 16-cycle motors in 1905. The first single-phase traction motor was developed by the Westinghouse Co. of America; it was a series-wound commutator motor working at 1 000 volts, 16 cycles.

From 1904 onwards, supply stations were being built all over the country. The smaller ones generated direct current, and in many d.c. stations batteries were used to take up peaks and night loads. These batteries were in use until a fairly recent date. Others generated alternating current single-phase, 2-phase, and 3-phase, at every possible frequency between 25 and 100 cycles, and at many different voltages.

The larger authorities were developing transmission systems, and the supply company now known as the South Wales Power Co. were the first with 11 000-volts transmission in this country. In America there were many sets generating at 10 000 volts and transmitting up to 69 000 volts. The American Falls Power and Light Co. transmitted 500 kW 25 miles at 33 500 volts. The longest line was the California Gas and Electric Co. which transmitted at 60 000 volts 232 miles, and the highest voltage was generated by the Grand Rapids Electrical Co., which transmitted 3 000 kW at 69 000 volts for a distance of 58 miles. All these were operating in 1908. The development of long transmission in the States was due to the use of water power.

In 1908 many of the larger authorities were using turbines, the largest recorded were the Chicago and the Edison Co.'s, each of which had two 14 000-kW machines made by the American General Electric Co. The largest in this country was that operated by the County of Durham who ran a 7 500-kW A.E.G. set, while Manchester had installed a 6 000-kW Willans set.

The design of electrical machinery was improving. Refinements such as compound coils and interpoles were added, and ball bearings were being fitted to customers' specifications. A.C. motors were being manufactured in large numbers, but d.c. motors predominated. The earlier a.c. motors in many cases favoured the American and Continental designs. The American design had a wide open-slot stator, and diamond-shaped former-wound coils dropped into the slots. The Continental design had semi-enclosed slots, the wires being dropped in one at a time and consisting of two or three layers of coils. The original American design is not now manufactured, but the Continental design is still used. The squirrel-cage rotors had the bars and rings connected by bolts or soldered; these gave considerable trouble and have almost entirely been replaced with brazed or

cast construction. The above remarks on motors apply only to industrial low-voltage machines.

High-voltage machines were being made, the stators being constructed with completely formed and insulated coils dropped into open slots. Another type was the hand-wound pull-through type, in which the wire was threaded through semi-closed slots. These types are seldom manufactured to-day. The disadvantage of the "pull through" type of winding is the large workshop space required, but a great many of these obsolete type motors are giving good service to-day.

The War period brought mass-production methods. Larger stations and longer transmission lines were erected to supply the new works, but many of the works had their own private plants and many favoured direct current.

At the conclusion of the War great developments were starting, namely the changing of plant, the scrapping of d.c. plant and the installing of a.c. systems. The larger supply authorities supplying direct current from rotary convertors and direct from d.c. generators were assisting the consumers to install a.c. apparatus and were supplying from transformer substations. In some towns single-phase, 2-phase, and 3-phase machines were in use, but later only the last-named were installed. A standard frequency of 50 was recommended, making it necessary for all the 25-, 40-, 60-, 80-, and 100-cycle supplies to change over the plant to 50-cycle supply. The industrial voltage of 400 was adopted as standard, and many supply authorities changed their plant and adopted this voltage. As can be imagined, this change-over was a big job, and in some industrial districts took the better part of 10 years' continuous work to complete.

The change-over called for a large number of new motors. Designs were improved and, owing to improvements in materials such as iron, steel, etc., the weights of machines were brought down. Ventilation was improved and the external-fan-cooled motor was taking the place of the heavy totally-enclosed machine. This motor has two casings—the inner casing completely encloses the windings, and the fan which is fitted outside the inner casing provides cool air in the space between the two casings. This type of motor is a number of years old but it has only been extensively advertised within the last few years.

The low-speed motors are being replaced by the higher-speed motors fitted with a gear reduction, making the motor and gearing one unit. With the change-over from direct to alternating current, need arose for the development of the 3-phase variable-speed motor.

There is an ever-increasing field for small motors, which are now manufactured in enormous quantities. It has brought the single-phase repulsion induction motor to the front—this type of motor is many years old and its present popularity is due to its high starting torque, which is required for driving refrigerator compressors. Another type of motor, also a refinement of an old type machine, is the split-phase capacitor motor, in which a condenser is fitted in one of the windings; this motor may replace the repulsion induction-type motor if it can produce sufficient starting torque.

Supply authorities were alive to the effects of bad power factor, so that, with the change-over, consumers were advised to install power-factor-correcting plant. This provided a new field in the manufacture of static condensers, and synchronous and auto-synchronous motors.

Welded steel-frame structures are replacing the heavy cast frames, but for standard machines of small size, produced in quantities, cast frames are still favoured. Flameproof enclosures have been adopted for collieries and works where this class of machine is called for, and asbestos insulation is being utilized for heavy-duty machines.

We now reach the last stage of our survey—the grid system with its turbines of 50 000 kW and above generating at 33 000 volts and running at 3 000 r.p.m. The mechanical engineer and the metallurgist have taken a leading and most important part in this development in producing the materials to withstand these high powers. Thus we have the oil-filled underground 60 000-volt cables, the 130 000-volt overhead lines, and switchgear tested to a maximum capacity of 250 000 kVA, and it is here interesting to note that the possibility of large switchgear manufacturers having testing stations, accepting the products of the smaller manufacturers for test, has now been realized, and arrangements between the Department of Scientific and Industrial Research and the larger manufacturers have been completed. Experiments with the hydrogen cooling of alternators and compressed-air blow-out for switchgear are being carried out, which will increase still further the output of generating plants. The heavy industries are taking up the electric drive, and motors of many thousands of horse-power are being installed. In 50 years of progress the power stations have increased in capacity from a few hundred kilowatts at 400 volts to 100 000 or more kilowatts at 33 000 volts. In 1894 Manchester had a total load of approximately 1 500 kW, open-type knife switches, fuses, and bare copper cables run in culverts, while in 1937–38 the number of units sold had increased to 532 millions, and remote-controlled oil-immersed circuit-breakers tested up to 250 000 kVA, 60 000-volt oil-filled cables, and 132 000-volt overhead lines, were employed.

In the works small hand-wound d.c. motors have given place to large motors of many thousands of horse-power. In 1893 there were 250 h.p. of motors at Dorman Long's works, and 600 h.p. at the Bedson Wire Works, while in 1936–37 67 million units were consumed at the Corby works of Stewart and Lloyd.

In the home many hundreds of thousands of fractional-horsepower motors are used, while lighting has changed from the 8-c.p. carbon lamp and arc lamp to the high-power discharge lamp. The traction load is falling, owing to the rapid displacement of the tramcar, but it may rise again with the advancement of railway electrification.

We electrical engineers are fortunate in being connected with this progressive industry. We were rather backward in the early days, but now the majority of the difficulties have been overcome. Some difficulties of course remain, but with goodwill and co-operation these also will be overcome.

MEASUREMENT OF THE THICKNESS OF METAL PLATES FROM ONE SIDE*

By A. G. WARREN, M.Sc., Member.†

(*Paper first received 5th January, and in final form 11th April,* 1938.)

SUMMARY

A method is described which is used for measuring the thickness of a metal plate of which only one side is readily accessible. No knowledge of the conductivity or permeability of the material is presumed. The method is particularly applied to the determination of the extent of corrosion.

The theory of the method when applied to an extensive plate is given. Only a brief indication of the theory underlying the application to plates of limited area is here published, but curves are given enabling the method to be applied in practice.

CONTENTS

(1) INTRODUCTION

One of the problems presented by practical engineering is the determination of the thickness of an extensive metal plate, one side only being generally accessible. The solution of the problem is of particular importance in cases where corrosion is likely to take place, such as the hulls of ships and the walls of boilers, gasholders, etc. The practical solution of drilling through the metal, measuring the thickness, and then plugging the hole, though effective, is crude and can only be used when a suitable opportunity is presented. One naturally looks for a simpler and non-destructive test which does not interfere with the normal use of the structure.

Methods of estimation of the thickness have been employed in the past which have depended upon a knowledge of the electrical conductivity of the material or, in the case of steel, of its magnetic permeability. The electrical test is perfectly sound in the case of pure materials of definite composition and physical condition; the magnetic test is subject to some uncertainty. In many cases the physical properties of the plate are not known with sufficient accuracy for any useful estimate of the thickness to be made from a simple test of conductance or permeance. Steel is notorious in this respect; work-hardening or heat treatment may change its electrical conductivity and its magnetic permeability in the ratio of 3 : 1. The method described here is a conductivity method which does not depend upon any previous knowledge of the specific conductivity of the material. Although the actual measurements made depend upon the conductivity, this quantity is automatically eliminated during computation and the essential relationships used are purely geometrical and do not depend upon the physical properties of the material (imagined homogeneous).

When corrosion is general the problem is simply that of determining the thickness of the plate at a number of places after it has been in use for some time. The apparatus employed may also be used in a search for local corrosion pits, which are not uncommon in some structures.

(2) GENERAL DESCRIPTION OF PRINCIPLES INVOLVED

(2.1) Two-dimensional flow of current.

If an electric current flows between two electrodes placed upon an indefinitely extensive thin metal sheet, the two electrodes may be considered as positive and negative sources of equal intensity from each of which the current spreads radially. The current density at any point on the sheet is the vector sum of the current densities contributed by the separate sources. The current density due to one source is inversely proportional to the distance from the source; the potential gradient is proportional to the current density. It therefore follows that the potential difference between any two points on the plate depends upon the relative distances between the points, and between the points and the sources; that is to say, upon the geometry of the figure and not upon its actual size.

* The Papers Committee invite written contributions, for consideration with a view to publication, on papers published in the *Journal* without being read at a meeting. Contributions (except those from abroad) should reach the Secretary of The Institution not later than one month after publication of the paper to which they relate.

† Research Department, Woolwich.

(2.2) Three-dimensional flow of current.

If instead of a thin sheet of metal the electrodes be placed upon a plane surface bounding an indefinitely thick mass of metal (semi-infinite sea) the flow of current from each source is radial in three dimensions and the current density is inversely proportional to the square of the distance from the source. For a given form of quadrangle upon the free surface, potential gradients are inversely proportional to the square of the linear dimensions, and the actual differences of potential between points, for a constant current, are inversely proportional to the linear dimensions.

(2.3) Conditions in a plate of finite thickness.

At big distances (compared with the thickness) the conditions in a plate of finite thickness are approximately those of two-dimensional flow (2.1); at short distances the conditions are approximately those of three-dimensional flow (2.2). This is illustrated by Fig. 1. Four contacts forming a square of side s are placed upon an extensive sheet of metal of thickness t. Current is passed through the plate between two adjacent contacts, and the potential difference between the other two contacts

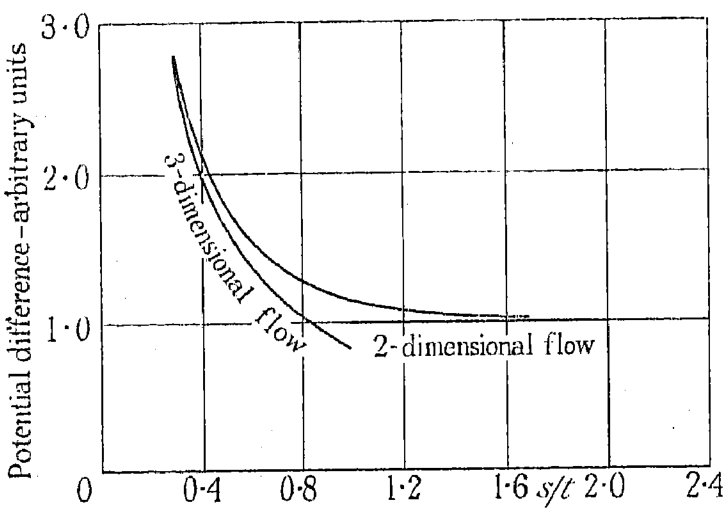


Fig. 1

is measured. So long as s/t is much greater than unity a nearly constant potential difference is obtained, but the potential difference rises rapidly when s/t becomes less than unity. The two asymptotic curves representing the conditions respectively of two-dimensional and three-dimensional flow are shown in the figure.

The determination of the conditions obtaining for distances of the same order as the thickness of the plate involves a considerable amount of calculation. The method of solution is indicated later. Its application to the problem in hand is, however, quite simple and is given immediately.

(3) PRACTICAL APPLICATIONS

(3.1) Contact squares.

For the purpose of applying current to the surface, and of picking off the potential difference between two specified points, use is made of "contact squares." These have different constructions according to their size. Those of square side of less than 1 in. employ four gramophone needles sliding in parallel cylindrical holes in an insulating disc (Fig. 2). In plan the axes of the holes form a perfect square. The disc is capable of a limited sliding motion within a hollow cylindrical holder. The butt ends of the needles have connecting wires soldered to them and project from the back of the disc.

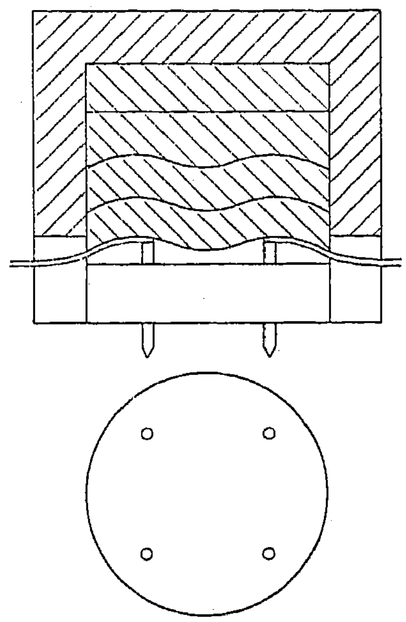


Fig. 2

Within the holder and bearing upon the butt ends of the needles is a pile of rubber discs. If the needle points rest upon a metal surface and pressure be applied to the holder the individual needles are forced into good electrical contact, even if the surface be painted or moderately rusty. Two *adjacent* needles are used as current contacts, the remaining pair as potential contacts. Contact squares are made up in a "scale of two" range—4 in., 2 in., 1 in.,

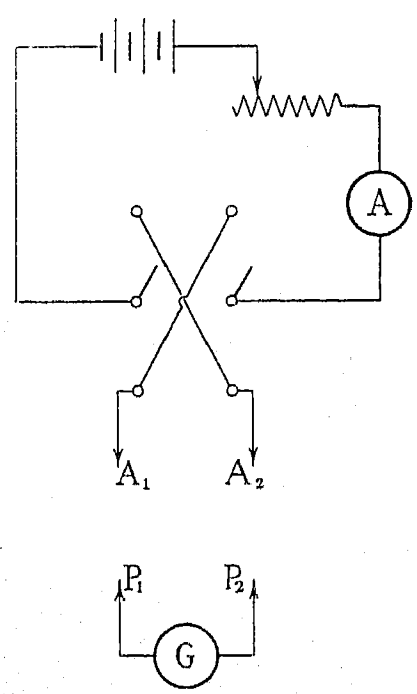


Fig. 3

$\frac{1}{2}$ in., $\frac{1}{4}$ in., and $\frac{1}{8}$ in., the defining size being the side of the square.

(3.2) Use of contact squares. Practical measurement of the thickness of indefinitely extensive plates

The circuit is shown in Fig. 3. The current is adjusted to a convenient value which is maintained constant there-

after. A common value employed with steel is 4 amperes. Thermal e.m.f.'s in the potential-measuring circuit are usually small but, to take account of these, readings are taken with reversed current. (For measurements of potential various instruments are available. A short-period galvanometer is commonly employed, sometimes a development of the Razek bridge.* The latter, as originally described, was much less sensitive than quite a simple moving-coil instrument. It has been developed to a point where it competes with a sensitive mirror galvanometer but is no easier to use. Further development appears possible.)

If one uses two successive contact squares of size definitely greater than the plate thickness, the potential difference obtained for a given current will be almost the same for both squares, but slightly greater for the smaller square. This ratio between the potential difference obtained with the smaller square to that obtained with the larger square increases rapidly as the size of the larger square is reduced towards the plate thickness. It is clear that the value of this ratio (R) gives a relation between the sides of the contact square and the thickness of the plate. This relation is expressed in a convenient practical form in Fig. 4. Thus if the potential difference obtained with a square of side a is R times the potential difference obtained with a square of side $2a$ then the thickness of the plate is $c \times a$, where c is obtained from Fig. 4. As a particular example, if $\frac{1}{2}$ in. and $\frac{1}{4}$ in. squares are used and the ratio R is $1{\cdot}41$, then c is $1{\cdot}6$ and the plate thickness is $1{\cdot}6 \times \frac{1}{4} = 0{\cdot}4$ in.

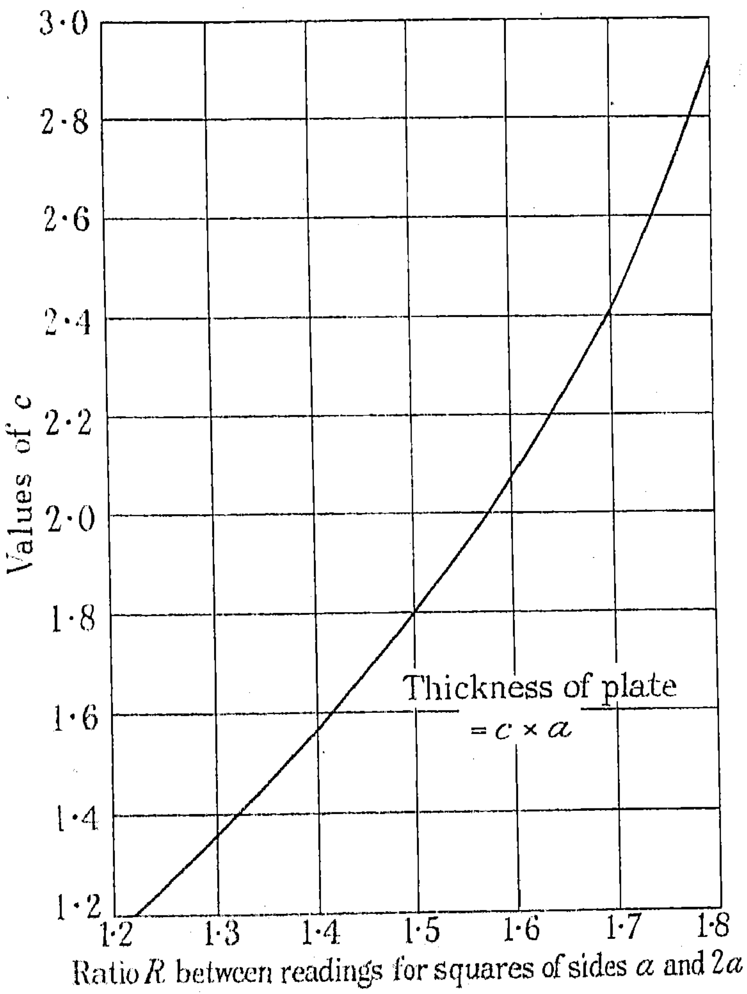


Fig. 4

* *Journal of the Franklin Institute*, 1935, vol. 219, p. 137.

Values of R between $1{\cdot}2$ and $1{\cdot}75$ are acceptable; the ranges of thickness thus obtained overlap.

(3.3) Measurement of the thickness of restricted plates.

Generally speaking, the method given above has been found to give extraordinarily accurate estimates of the thickness of metal plates. Errors as great as 3 per cent are uncommon. Occasionally, however, the effective or electrical thickness of a plate may be less than its actual thickness. Such a condition may be brought about by "lamination," a serious source of weakness. In cases where this condition is suspected the specimens available for test are often of restricted size and account must be taken of the restriction. There are indeed cases, where there is no suspicion regarding quality, where an extensive area is comprised of sheets of limited area riveted together. The electrical connection between the sheets is negligible compared with the conductivity of each sheet, and it is necessary to examine the error which may be introduced by the restricted size of the individual

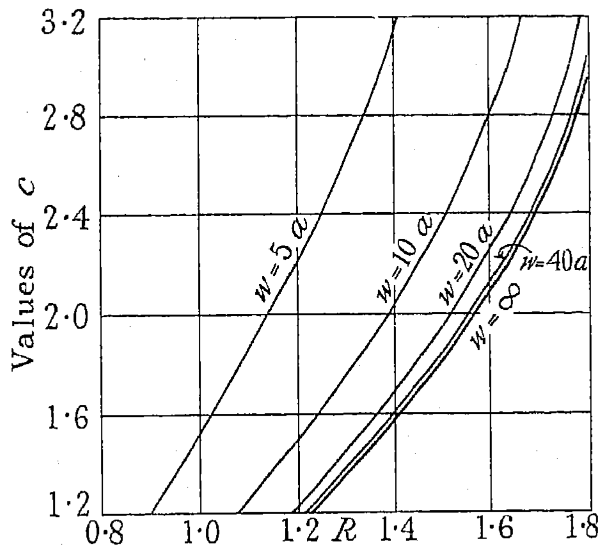


Fig. 5

sheet and, if necessary, correct for it. It can be shown that when contact squares are used with the line joining the potential contacts parallel to the length of the plate the important restriction is the width w. Account is taken of this restriction in Fig. 5. From the curves there plotted the thickness of a plate of limited area can be estimated.

(3.4) Detection of corrosion pits.

Where localized corrosion is suspected the use of a contact square having a side s about equal to the nominal thickness of the plate is found to be effective. On approaching a corrosion pit there is a considerable rise in the difference of potential measured.

(4) THEORY OF METHOD. INDEFINITELY EXTENSIVE PLATE

(4.1) Flow of current through an extensive thin plate.

For a current source of strength i in a thin plate of thickness t, the current density at a distance r is $i/(2\pi rt)$, the potential gradient $\rho i/(2\pi rt)$ (ρ being the resistivity), and the potential difference between two points distant r_1 and r_2 is $\dfrac{\rho i}{2\pi t}\,\mathrm{logh}\,\dfrac{r_2}{r_1}$.

(4.2) Flow of current into an infinite sea of resistivity ρ.

For a source of strength i the current density at a distance r is $i/(4\pi r^2)$ and the potential gradient $\rho i/(4\pi r^2)$. The potential difference between two points distant r_1 and r_2 is $\frac{\rho i}{4\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$.

(4.3) Flow of current into a semi-infinite sea.

The source i is imagined to be immediately below the surface C, the current radiating in all directions. Since there is no flow through C a proximate image of strength i immediately above the surface must be imagined (Fig. 6).

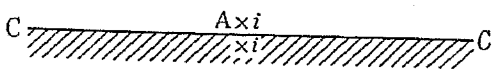


Fig. 6

That is to say, conditions below C are the same as they would be with a source of strength $2i$ at the point A, the sea being considered infinite instead of semi-infinite. The potential at a distance r is thus $\rho i/(2\pi r)$.

(4.4) Flow of current into an indefinitely extensive plate of thickness t.

The source is of strength i; the plate is bounded by the parallel surfaces C_1 and C_2. It is imagined that a source of strength $2i$ is at A on C_1 (Fig. 7). Since no current crosses C_2 an image $2i$ must be assumed at B. But the image at B gives rise to a current crossing C_1 which must be neutralized by a source $2i$ at C, which

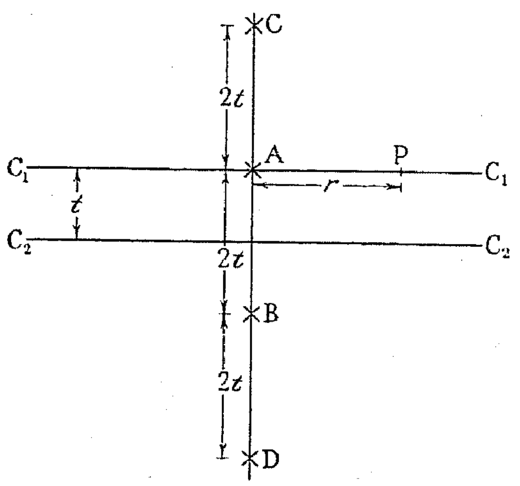


Fig. 7

gives rise to a current crossing C_2 which must be neutralized by a source $2i$ at D, and so on. At a point P on the surface C_1, distant r from A, the potential is

$$E = \frac{\rho i}{2\pi}\left\{\frac{1}{\mathrm{AP}} + \frac{1}{\mathrm{BP}} + \frac{1}{\mathrm{CP}} + \frac{1}{\mathrm{DP}} \cdots\right\}$$

or

$$E = \frac{\rho i}{2\pi}\sum\frac{1}{\sqrt{(r^2 + 4n^2t^2)}}$$

where n has all integral values from $-\infty$ to $+\infty$, including zero. This may be written

$$E = \frac{\rho i}{4\pi t}\sum\frac{1}{\sqrt{(\theta^2 + n^2)}}, \quad \text{where } \theta = r/(2t)$$

This series is divergent but the difference of potential between any two points is finite. For purposes of computation in any practical case it has been found convenient to express the potential with respect to a point distant some standard multiple of the thickness t.

If $S_\theta = \sum\frac{1}{\sqrt{(\theta^2 + n^2)}}$ and $S_\phi = \sum\frac{1}{\sqrt{(\phi^2 + n^2)}}$

then, although S_θ and S_ϕ are individually infinite, $S_\theta - S_\phi$ is finite. A value found convenient to assign to ϕ is 2, and then $f(\theta)$ may be defined as $f(\theta) = S_\theta - S_2$, giving

$$f(\theta) = \left(\frac{1}{\theta} - \frac{1}{2}\right) + 2\sum\left(\frac{1}{\sqrt{(\theta^2 + n^2)}} - \frac{1}{\sqrt{(2^2 + n^2)}}\right)$$

where n has all integral values from 1 to infinity.

The terms of this series are but slowly convergent, and to obtain sufficiently accurate values of $f(\theta)$ values of n up to about 30 must be included if direct summation is to be attempted. Computation may, however, be much

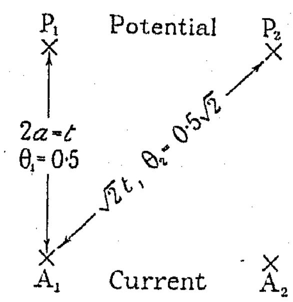


Fig. 8

reduced in such a series by making use of the following identity:—

$$\sum_{1,2\ldots}^{\infty} f(\theta, n) \simeq f(\theta, 1) + f(\theta, 2) \ldots f(\theta, m) + \int_{m+\frac{1}{2}}^{\infty} f(\theta, n)dn$$

Sufficient accuracy is obtained when

$$\int_{m+\frac{1}{2}}^{\infty} f(\theta, n)dn = f(\theta, m+1) + \int_{m+\frac{3}{2}}^{\infty} f(\theta, n)dn$$

within the limits required. In the case of this particular series $f(\theta, m) = 2\left[\frac{1}{\sqrt{(\theta^2 + m^2)}} - \frac{1}{\sqrt{(2^2 + m^2)}}\right]$.

$$\int_{m+\frac{1}{2}}^{\infty} f(\theta, n)dn = 2 \operatorname{logh}\frac{m + \frac{1}{2} + \sqrt{[2^2 + (m + \frac{1}{2})^2]}}{m + \frac{1}{2} + \sqrt{[\theta^2 + (m + \frac{1}{2})^2]}}$$

In this manner values of $f(\theta)$ were calculated for each increment of the argument of $0 \cdot 1$ from $0 \cdot 1$ to $1 \cdot 5$. When $\theta \nless 1 \cdot 5$ it is sufficient to assume that $f(\theta) = 2 \operatorname{logh} 2/\theta$. Owing to the rapid and varying rate of change of $f(\theta)$, interpolation is not simple. It is made much easier by tabulating $\theta . f(\theta)$. These values are given in the Table, which has been used in determining Fig. 4. For any contact square used the difference of potential obtained per unit current is proportional to $f(\theta_1) - f(\theta_2)$, where $\theta_1 = r_1/(2t)$, and $\theta_2 = r_2/(2t)$, $r_1 = A_1P_1$ and $r_2 = A_1P_2$

Table

VALUES OF $\theta \, . f(\theta)$, WHERE $\theta = r/(2t)$

	0	1	2	3	4	5	6	7	8	9
	111	111	110	109	108	108	106	105	103	102
0·1	1·1143	1·1254	1·1365	1·1475	1·1584	1·1692	1·1800	1·1906	1·2011	1·2114
	100	99	98	97	96	94	92	90	89	87
0·2	1·2216	1·2316	1·2415	1·2513	1·2610	1·2706	1·2800	1·2892	1·2982	1·3071
	85	83	81	80	77	75	74	72	69	67
0·3	1·3158	1·3243	1·3326	1·3407	1·3487	1·3564	1·3639	1·3713	1·3785	1·3854
	65	63	61	59	57	54	52	49	48	46
0·4	1·3921	1·3986	1·4049	1·4110	1·4169	1·4226	1·4280	1·4332	1·4381	1·4429
	43	41	39	37	34	32	29	27	25	22
0·5	1·4475	1·4518	1·4559	1·4598	1·4635	1·4669	1·4701	1·4730	1·4757	1·4782
	20	18	16	13	11	9	6	4	2	0
0·6	1·4804	1·4824	1·4842	1·4858	1·4871	1·4882	1·4891	1·4897	1·4901	1·4903
	2	5	7	9	11	13	16	18	20	22
0·7	1·4903	1·4901	1·4896	1·4889	1·4880	1·4869	1·4856	1·4840	1·4822	1·4802
	24	26	28	31	33	35	37	39	40	43
0·8	1·4780	1·4756	1·4730	1·4702	1·4671	1·4638	1·4603	1·4566	1·4527	1·4487
	45	47	48	51	54	56	57	59	60	63
0·9	1·4444	1·4399	1·4352	1·4304	1·4253	1·4199	1·4143	1·4086	1·4027	1·3967
	64	66	68	70	72	74	76	77	79	81
1·0	1·3904	1·3840	1·3774	1·3706	1·3636	1·3564	1·3490	1·3414	1·3337	1·3258
	82	84	86	88	89	91	93	94	96	98
1·1	1·3177	1·3095	1·3011	1·2925	1·2837	1·2748	1·2657	1·2564	1·2470	1·2374
	99	101	103	105	106	107	109	111	112	114
1·2	1·2276	1·2177	1·2076	1·1973	1·1868	1·1762	1·1655	1·1546	1·1435	1·1323
	115	116	118	120	121	123	124	125	126	128
1·3	1·1209	1·1094	1·0978	1·0860	1·0740	1·0619	1·0496	1·0372	1·0247	1·0121
	129	131	132	134	135	136	138	139	140	142
1·4	0·9993	0·9864	0·9733	0·9601	0·9467	0·9332	0·9196	0·9058	0·8919	0·8779
1·5	0·8637									

(Fig. 8). The numerical values given on Fig. 8 are for a square of side equal to the thickness of the plate.

A simpler Table might be set out to deal with this problem of contact *squares*, but the Table given is of much wider application. Clearly it can be used to take account, when required, of any errors in the shape or size of actual squares. It can also be used to deal with any disposition of electrodes which may be desirable in particular cases.

In the discussion above, account has only been taken of the positive source. With a normal symmetrical disposition the negative source produces an equal difference of potential. In the case of an asymmetrical distribution similar calculations must be made for both positive and negative sources.

(5) THEORY OF METHOD. RESTRICTED PLATE

When the plate is limited not only in thickness but also in width to $w = ps$ and in length to $l = qs$ the conditions within the plate can be determined by imagining a space lattice of images consisting of the line of images shown in Fig. 7, together with all its possible reflections and re-reflections in the planes bounding the plate. These images may be considered to be on an infinite series of planes parallel to the edges bounding the width of the plate. For a thin plate, and for a thick plate except for the plane passing through the source, it may be shown that for all the images in a particular plane distant λs from the source

$$\sum f(\theta_1) - f(\theta_2) = \operatorname{logh} \left\{ \frac{\cosh \gamma + 1}{\cosh \delta + 1} \cdot \frac{\cosh \gamma - \cos \theta}{\cosh \delta - \cos \theta} \right\}$$

where $\qquad \gamma = (1 + \lambda)\dfrac{\pi}{p}, \quad \delta = \lambda \dfrac{\pi}{p}, \quad \theta = \dfrac{\pi}{p}$

For the particular plane passing through the source in a thick plate this value is exceeded by the difference between $f(\theta_1) - f(\theta_2)$ and $\operatorname{logh}(r_2^2/r_1^2)$. The method of procedure in calculating for the restricted plate is thus: First solve the problem for the thin plate, including as many planes left and right (positive and negative) as is necessary, and then add to the result so obtained the excess of $f(\theta_1) - f(\theta_2)$ over $\operatorname{logh}(r_2^2/r_1^2)$ for the original source.

This is the method which has been adopted in determining the curves of Fig. 5. The general theory has been tested upon a plate 10 in. square, using contact squares from $\frac{1}{2}$ in. to 10 in., and has been found experimentally to be correct.

ACKNOWLEDGMENTS

The author wishes to express his appreciation of the interest and encouragement of the Director of Radiological Research, Dr. V. E. Pullin, C.B.E.

The paper is published by permission of the Ordnance Committee.

A SENSE-FINDING DEVICE FOR USE WITH SPACED-AERIAL DIRECTION-FINDERS*

By R. A. FEREDAY, Ph.D.

(*Paper first received* 21*st April, and in final form* 19*th May*, 1938.)

SUMMARY

A simple method is described for the rapid determination at a receiver of the sense of the direction of arrival of radiation from any transmitting station. A radio bearing of the station is taken in the usual manner with a four-aerial Adcock direction-finding system, and a second observation of minimum received signal is made after certain modifications to the electrical connections between the aerials have been effected by switching. The two observations are sufficient to determine without the usual ambiguity of 180° the bearing of the transmitting station at the receiver. The method is particularly suitable for use on high frequencies and with the visual type of receiver incorporating a cathode-ray tube.

(1) INTRODUCTION

The figure-of-eight polar diagram of direction-finders of the loop or spaced-aerial types leads to the usual ambiguity of 180° in the determination of the bearing of a transmitting station at the receiver. By the addition of a vertical aerial to the system the receiver polar diagram can be made to be of the form of a cardioid, in which case the bearing of any station can be obtained without any ambiguity. The cardioid receiver polar diagram, however, is obtained only for critical adjustment of both the relative phases and amplitudes of the two voltages impressed across the receiver input terminals from the directive and non-directive aerials. The degree to which this adjustment is possible with the usual type of direction-finder, modified for sense determination, is not sufficient for practical use of the receiver over a wide frequency range, especially on the shorter wavelengths. In particular, it is difficult to obtain any sense determination with the cathode-ray-tube type of receiver. An arrangement† has been described for determining the sense of the bearing of a transmitting station with such a receiver, but it involves considerable complexity in addition to being subject to difficulty in securing the required adjustment of the e.m.f. injected from the vertical aerial.

The method described below for the sense determination of a bearing involves only slight modification to any existing four-aerial Adcock system, and the procedure is extremely simple. After a bearing has been obtained in the normal manner, the electrical connections between the aerials are altered by means of a switch and a second observation is made. As is shown below, this second measurement is sufficient to determine the "sense" of the original bearing.

(2) SIMPLE SYSTEM APPLICABLE TO LONG WAVES

Consider a four-aerial Adcock system and suppose that radiation is incident on this array in a direction making the angle θ with the meridian. The phase-difference between the voltages induced in the north (N) and south (S) aerials is

$$\frac{2\pi d}{\lambda}\cos\theta$$

in which d is the distance between the aerials and λ the wavelength of the incident radiation. As these voltages are combined at the receiver in opposition, the voltage applied to the N-S field coil of the goniometer is

$$2E\sin\left(\frac{\pi d}{\lambda}\cos\theta\right) \quad . \quad . \quad . \quad . \quad (1)$$

in which E is the voltage due to either aerial. Similarly, the voltage in the E–W goniometer field coil is

$$2E\sin\left(\frac{\pi d}{\lambda}\sin\theta\right) \quad . \quad . \quad . \quad . \quad (2)$$

In measuring the bearing of a station the goniometer search-coil is rotated until the resultant of the two e.m.f.'s induced in it by the field coils is zero. This condition occurs when the search coil makes the angle ϕ with the N–S field coil, so that

$$\tan\phi = \frac{\sin\left(\frac{\pi d}{\lambda}\cos\theta\right)}{\sin\left(\frac{\pi d}{\lambda}\sin\theta\right)} \quad . \quad . \quad . \quad (3)$$

For aerial spacings small compared with the wavelength, equation (3) reduces to

$$\tan\phi = \cot\theta \quad . \quad . \quad . \quad . \quad . \quad (4)$$

the solution of which is

$$\phi = \theta + \pi/2 \quad . \quad . \quad . \quad . \quad . \quad (5a)$$

and

$$\phi = \theta + 3\pi/2 \quad . \quad . \quad . \quad . \quad . \quad (5b)$$

Equations (5*a*) and (5*b*) show the usual ambiguity of 180° in the location of a transmitting station by means of

* Official communication from the National Physical Laboratory.

The Papers Committee invite written contributions, for consideration with a view to publication, on papers published in the *Journal* without being read at a meeting. Contributions (except those from abroad) should reach the Secretary of The Institution not later than one month after publication of the paper to which they relate.

† "The Cathode Ray Tube in Radio Research," p. 182 (H.M. Stationery Office).

any standard type of radio direction-finder. This ambiguity can be overcome, however, by making a second observation with one of the goniometer field coils connected to a single vertical aerial instead of to, say, the E–W Adcock pair. With this arrangement the e.m.f. induced by the N–S Adcock aerials in the goniometer search-coil, when the latter makes an angle ψ with the N–S field coil, is proportional to

$$\sin\left(\frac{\pi d}{\lambda}\cos\theta\right)\cos\psi$$

The e.m.f. induced in the search-coil by the single aerial connected to the normal E–W goniometer field-coil is proportional to $\sin\psi$. In order that these e.m.f.'s may be compared by the goniometer, it is necessary to include a phase-changing device in one circuit to bring them into phase. The resultant e.m.f. E in the search-coil is given, therefore, by

$$E = a\sin\left(\frac{\pi d}{\lambda}\cos\theta\right)\cos\psi + b\sin\psi \quad . \quad . \quad (6)$$

in which a and b are constants depending on the construction of any particular installation.

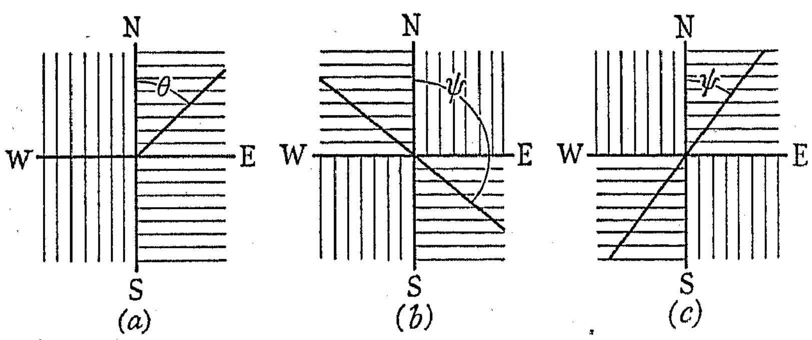


Fig. 1.—Relation between bearing θ of station and observed value of ψ for minimum received signal with combination of North and South Adcock aerials with non-directional aerial.

(*b*) a and b (eqn. 6) of same sign.
(*c*) a and b (eqn. 6) of opposite sign.

The phase-difference between the e.m.f.'s induced by the incident radiation in the Adcock aerial pair and the single vertical aerial is approximately $\frac{1}{2}\pi$. In the case of the aerials which are normally short compared with the wavelength, their impedance is mainly reactive, with the result that the current in them leads by $\frac{1}{2}\pi$ the e.m.f. induced in them. The impedance of the central aerial is also mainly reactive, but the aerial current may be made to have approximately the same phase as the e.m.f. by the insertion of a large resistance in series with the aerial. With this arrangement the output voltages of the N–S Adcock-aerial pair and the central aerial have approximately the same phase and can be applied to the two goniometer field-coils. The insertion of the resistance in series with the central aerial has the additional advantage that the attenuation introduced in this way makes the currents in the two goniometer field-coils of comparable magnitude.

It is shown in the Appendix that for the angles θ given in Fig. 1(*a*) which the direction of a station makes with the meridian at the receiver, the observed values of ψ determined from equation (6) for a signal minimum are given in Figs. 1(*b*) and 1(*c*) when the combination of the N–S Adcock aerials and the central aerial with added resistance is used. Figs. 1(*b*) and 1(*c*) correspond to the two possible conditions in which the constants a and b in equation (6) are respectively of the same, or of opposite, sign. The relative signs of these two factors for any particular installation are determined most simply by making sense observations on a local transmitter. If the E–W Adcock aerials and the vertical aerial were used, the relation between the bearing θ of a station and ψ the goniometer reading for minimum signal would be given by Figs. 2(*a*), 2(*b*), and 2(*c*). Whether Fig. 2(*b*) or Fig. 2(*c*) applied to the particular installation used would again have to be determined by observations on a local transmitter.

Suppose the station under observation lies in the N–E quadrant with respect to the receiver, and that observations with the local transmitter showed that when the E–W Adcock receiving aerials were replaced by a vertical aerial θ and ψ were related according to Figs. 1(*a*) and 1(*b*). A measurement with the complete Adcock system will show that the station lies at a certain angle to the meridian but in either the N–E or S–W quadrants. When the E–W Adcock aerials are replaced by the vertical aerial, however, the minimum received field condition is obtained when the goniometer search-coil is orientated so as to give a reading in the N–W or S–E

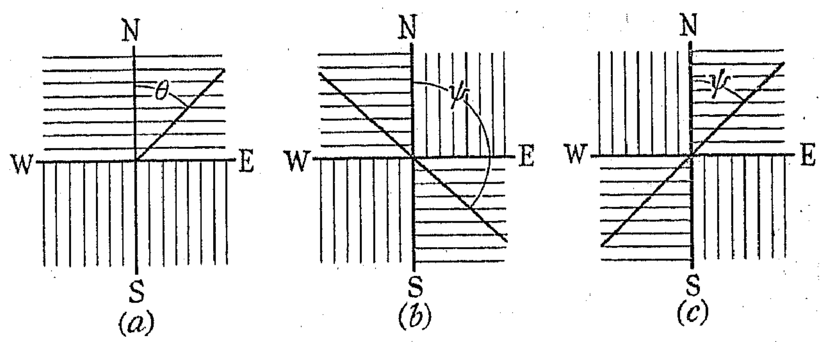


Fig. 2.—Relation between bearing θ of station and observed value ψ for minimum received signal with combination of East and West Adcock aerials with non-directional aerial.

quadrants. It will be seen from Figs. 1(*a*) and 1(*b*) that, for this condition to apply, the observed station must lie to the east of the meridian at the receiver. The two observations of minimum signal with the complete Adcock system and one Adcock pair with central aerial are sufficient, therefore, to determine without ambiguity the direction of arrival of the incident radiation.

It will be noted from Fig. 1 that if the station under observation lies due north or south of the receiver no sense resolution is possible. Similarly, for the conditions applying to Fig. 2, no sense resolution can be made in this case for radiation incident in the E–W direction. By adopting a system in which either Adcock-aerial pair may be used in conjunction with the vertical aerial for sense observation, these two directions of "no sense" resolution may be avoided.

(3) SYSTEM SUITABLE FOR USE ON SHORT WAVELENGTHS

The system described above is not suitable for use on short wavelengths unless the phase-delays introduced by the long leads from the aerials to the receiver are matched by an equivalent phase-delay introduced in the central aerial circuit. The complication can be avoided, how-

ever, if the non-directional aerial output is obtained from the second Adcock-aerial pair instead of from the central aerial. In order to make this second Adcock-aerial pair approximately non-directional, the two component aerial outputs must be combined additively instead of in opposition. This arrangement simulates closely that used on longer wavelengths with the single non-directional aerial, but all phase-delays introduced between the aerials and the receiver remain of comparable magnitude in the new arrangement. High resistances in series with the non-directional unit are still required, in order that the currents in the two goniometer field-coils may be approximately in phase.

The analysis of the case in which both Adcock-aerial pairs are used for sense observations is very similar to that for one Adcock-aerial pair and the single vertical aerial. The results given in Figs. 1 and 2 apply to the new system, the particular condition corresponding to any installation being again determined with the use of a local transmitter. This system also suffers from the fact that there is a direction of "no sense" resolution with either Adcock pair used as the non-directional unit, but, by arranging that either pair of Adcock aerials is used for this purpose, sense resolution is possible for all directions of arrival of the incident radiation.

(4) EXPERIMENTAL INVESTIGATION

There is a direction with both the sense-finding arrangements described above, for which no sense resolution is possible unless either pair of the Adcock aerials can be used as the directive element. It is desirable, in practice, that the relative amplitudes of the currents in the two goniometer field-coils should be such that this sector for no sense resolution is as narrow as possible. In testing various arrangements, measurements were made with a local transmitter set up at an angle of 90° from the centre of the "no sense" resolution sector of an Adcock-aerial pair and central aerial system. In the earlier experiments, the N–S aerials of a four-aerial Adcock system rather similar to that described by Barfield and Ross,* were replaced for sense-finding by a vertical aerial having characteristics as similar as possible to those of the individual aerials of the system. The curves in Fig. 3 show the results obtained with this arrangement at three frequencies in the neighbourhood of aerial resonance (6·6 Mc./sec.) when resistances of different values were inserted (as shown inset) in series with the single aerial. The dotted portions of the curves correspond to observations requiring swings greater than ± 10° for the determination of the minimum received

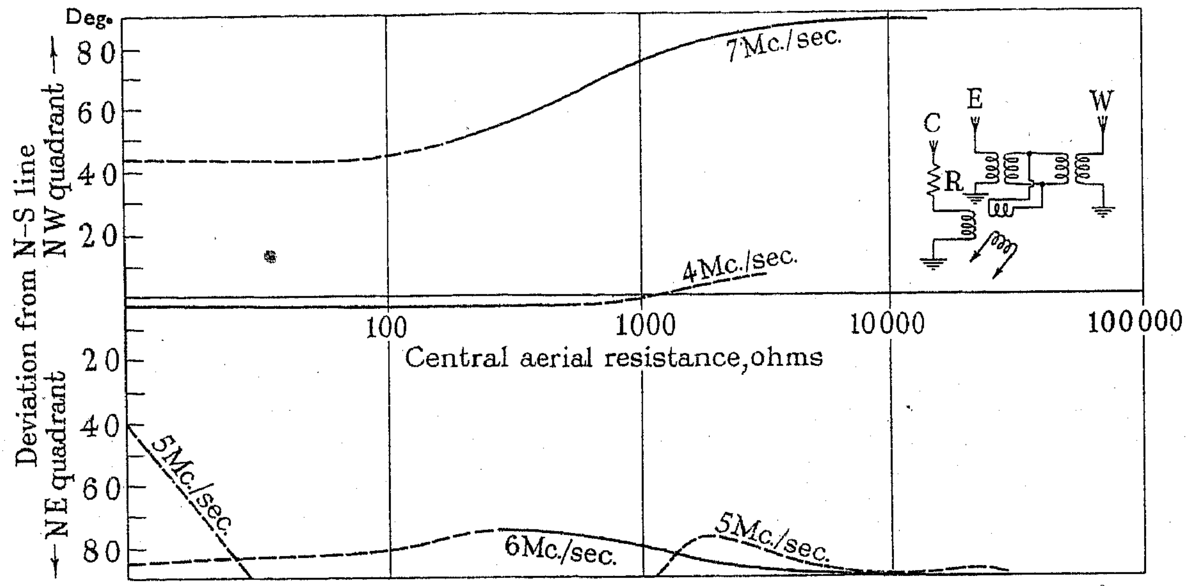


Fig. 3

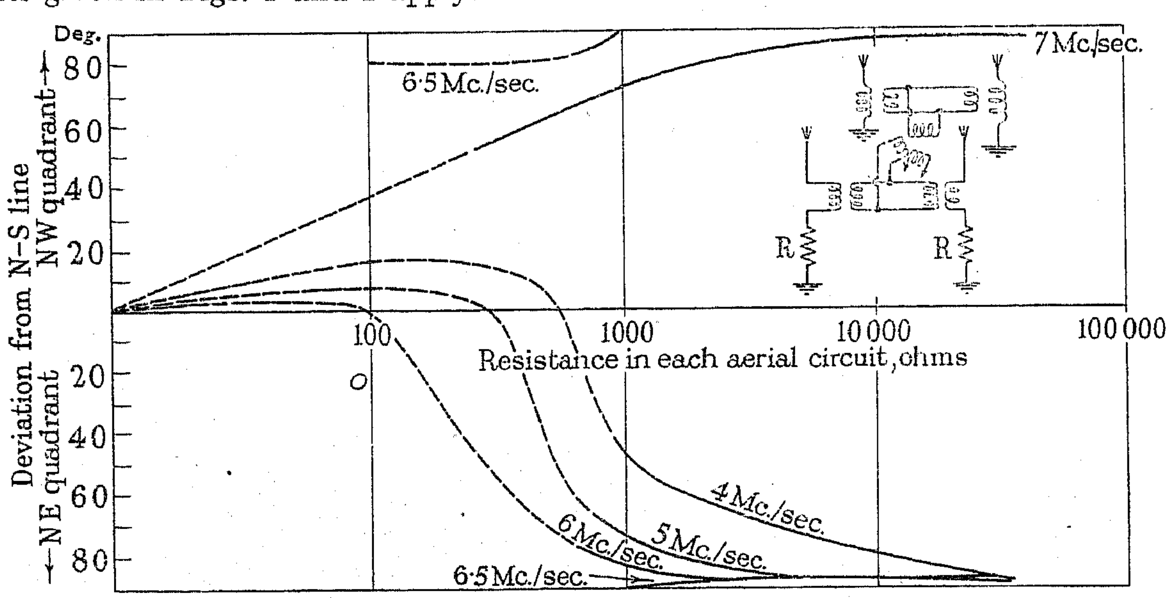


Fig. 4

* *Journal I.E.E.*, 1937, vol. 81, p. 682.

signal condition, and therefore to conditions unsuitable for practical purposes. With resistances of between 500 and 2 000 ohms good sense-finding measurements were possible even for radiation almost in the direction of "no-sense" resolution. The difference of approximately 180° in the sense readings at 6 and 7 Mc./sec. was due to the resonance of the aerial system occurring between these frequencies. At 5 Mc./sec., resistance values exceeding 50 000 ohms were required for proper phase adjustment, but the attenuation introduced in this way was such that the output from the central aerial was not sufficient for sense indication. The correct phase relationship at 4 Mc./sec., on the other hand, required such a small resistance that the output from the central aerial swamped that of the E–W Adcock pair.

The improvement obtained when the central aerial

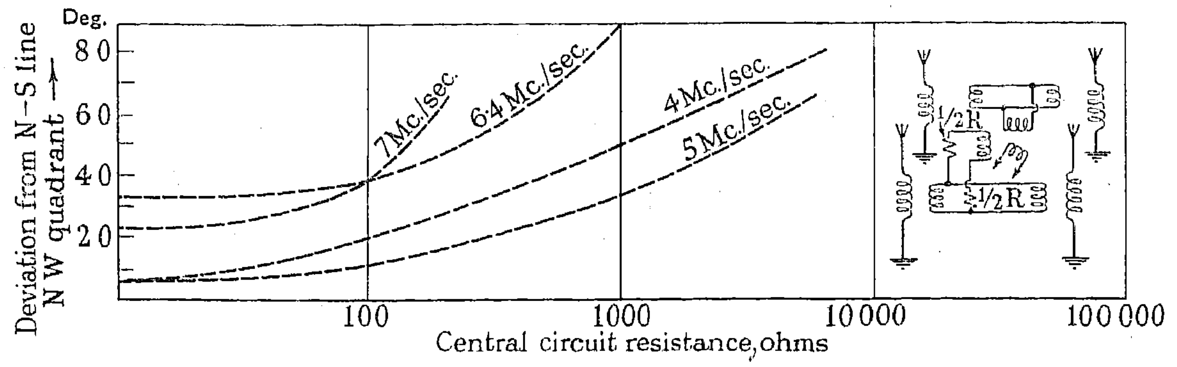


Fig. 5

Table

Frequency, Mc./sec.	Station	Location	Normal		Sense A		Sense B	
			Bearing, deg.	Swing, deg.	Reading, deg. >90 = E <90 = W	Swing, deg.	Reading, deg. >180 = S <180 = N	Swing, deg.
4·0	G5PG	Ditton Park	352	2	85	10	179	2
4·6	RUK	Stalinabad	85	50	95	10	167	30
4·8	RVS	Mourmansk	35	30	98	25	173	15
5·0	OEY	Deutsch-Altenburg	102	25	95	12	193	20
5·3	WEU	New Brunswick, N.J.	290	20	84	15	165	30
5·6	OXZ	Lyngby	57	20	95	10	168	20
6·7	OZS	Skamlebäk	50	20	102	20	160	20
6·7	IEO	Rome	135	20	100	20	190	20
6·7	OLH	Prague	95	10	100	20	240	50
7·8	WIF	Brentwood, N.Y.	290	80	80	40	160	60
7·9	FTY	S. Assise	143	15	110	40	190	20
8·1	JNO	Nagoya	35	20	110	40	165	15
8·4	OXZ	Lyngby	No bearing	Flat	100	40	170	40
8·4	WSL	Amagansett	285	50	75	20	167	30
8·5	DAN	Norddeich	63	30	107	20	156	20
8·6	ORM	Ruysselede	99	20	110	10	225	20
9·0	HBC	Berne	130	20	105	10	192	20
9·1	IBF	Rome	131	20	103	10	192	20
9·1	HAT4	Budapest	107	15	102	15	202	15
9·2	GIV	Oxford	304	10	77	5	167	5
9·3	LCB	Oslo	40	10	107	10	167	10
9·3	JUJ	Tokyo	30	60	105	50	170	40
9·6	RAL	Moscow	65	30	104	20	160	30
9·6	DJA	Zeesen	82	10	102	10	255	10
9·8	EAM2	Arranjuez	185	10	40	60	191	10
9·8	DFE	Nauen	75	20	105	20	165	40
9·8	LSI	Monte Grande	220	20	75	20	190	20
10·0	OLG	Prague	93	10	104	10	(See text)	
10·0	IES	Rome	135	20	97	15	185	50
10·0	KUW	Manila, Philippine Is.	50	60	105	90	170	60
10·0	FTL	S. Assise	140	20	105	20	195	30

was replaced by a reversed Adcock-aerial pair can be seen from the curves in Fig. 4, which show that at any frequency there was a relatively wide range of resistance values for which the necessary degree of phase and amplitude matching was satisfied. This is particularly evident at frequencies near the resonant frequency of the aerial system. The practical frequency range of this Adcock system was limited by aerial resonance at about 4 Mc./sec. and by secondary-circuit resonance at 10 Mc./sec. Between these two frequencies the sense-finding device functioned satisfactorily. It will be seen from the curves in Fig. 5 that, with the system shown inset in that figure, unsatisfactory results were obtained when the phase-adjusting resistances were inserted in the circuit coupling the two aerials forming the non-directional unit to the goniometer.

Measurements made on ground stations with a permanent installation using the sense-finding circuit shown in Fig. 4 are given in the Table. The observed bearing of each station made with the normal Adcock system is given in the fourth column, and the corresponding sense observations with the two possible aerial connections in the sixth and eighth columns. The interpretation of

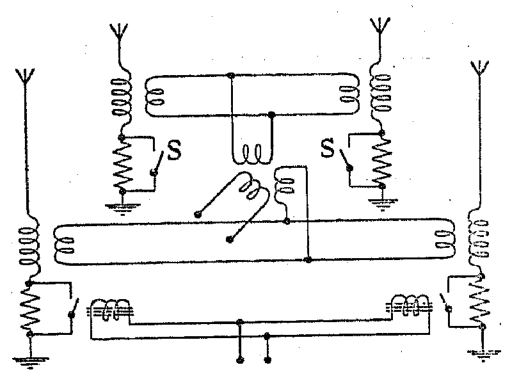


Fig. 6

these sense observations is possible from the key given above each column. The swing of the goniometer search-coil required for any observation is shown in the column immediately succeeding that giving the observation. It will be noted that sense determination was possible for all stations with either pair of aerials as the non-directive element. In the case of one station (OXZ) the required swing when taking a bearing was so great that the bearing could not be determined. The two sense observations, however, were more definite and were sufficient to determine the quadrant in which the bearing of the station lay. The station OLG (bearing normally 93°) showed variations in bearing from angles less than 90° to values greater than 90°. The sense indication for discrimination between N and S showed corresponding swings.

A sense-finding system similar to that described above and shown diagrammatically in Fig. 6 has been in use for some time with both visual and aural types of receiver. In the installation with visual recording, the time taken to obtain a sense indication on a normal ambiguous bearing is negligible, so that the system is at no disadvantage compared with one in which an unambiguous bearing is given directly. It was found experimentally with the permanent installation employing aural reception that an aerial resistance of 5 000 ohms was satisfactory. A carbon resistance of this value was connected to each aerial near its base and was normally short-circuited by a mercury switch, the operating relay of which was located at some distance from it and was operated by a mechanical link of insulating material. In this way the leads carrying the relay current were kept well away from the aerials and feeders, and so were prevented from forming a low-impedance circuit between the aerials at the signal frequency. The switch controlling the relay was so arranged that when the resistances were inserted in the aerials the connections of the latter to the goniometer were also reversed, so that the change from a normal Adcock direction-finding system to the modified sense-finding arrangement was made in one operation. By using either pair of Adcock aerials as the non-directional element, sense resolution was possible for radiation incident in any direction. In order to simplify the interpretation of results, small replicas of Fig. 3 or Fig. 4 were illuminated automatically according to the aerial arrangement in use.

(5) ACKNOWLEDGMENTS

The work described above formed part of the programme of the Radio Research Board, and this paper is published by permission of the Department of Scientific and Industrial Research. The author desires to acknowledge his indebtedness to Dr. J. S. McPetrie for help in the method of presentation of the paper, and to Mr. R. E. Burgess for assistance in the experimental work.

APPENDIX

$$E = a \sin\left(\frac{\pi d}{\lambda}\cos\theta\right)\cos\psi + b\sin\psi \quad . \quad . \quad (6)$$

In order to find the minimum value of $|E|$ with respect to ψ it is convenient to determine the minimum value of E^2.

$$E^2 = a^2\sin^2\left(\frac{\pi d}{\lambda}\cos\theta\right)\cos^2\psi + b^2\sin^2\psi$$
$$+ ab\sin\left(\frac{\pi d}{\lambda}\cos\theta\right)\sin 2\psi \quad . \quad (7)$$

The minimum value of E^2 must occur when the third term in equation (7) is negative. Four conditions are possible:—

(i) *a and b same sign, cos θ positive.*

For these conditions $\sin 2\psi$ is negative, that is

2ψ lies between 180° and 360°, or 540° and 720°,

or ψ* lies between 90° and 180°, or 270° and 360°.

(ii) *a and b same sign, cos θ negative.*

For these conditions $\sin 2\psi$ must be positive.

Therefore 2ψ lies between 0° and 180°, or 360° and 540°,

or ψ lies between 0° and 90°, or 180° and 270°.

(iii) *a and b opposite sign, cos θ positive.*

This gives the same values of ψ as Case (ii).

(iv) *a and b opposite sign, cos θ negative.*

This gives the same values of ψ as Case (i).

* ψ is measured from the N-S line.

THE DEPENDENCE ON FREQUENCY OF THE TEMPERATURE-COEFFICIENT OF INDUCTANCE OF COILS*

By H. A. THOMAS, D.Sc., Member.

(*Paper first received 6th April, and in final form 9th June,* 1938.)

SUMMARY

Evidence is given that the temperature-coefficient of inductance of coils is dependent on frequency, owing to the change with temperature of the current distribution over the conductor cross-section. The effect is of importance only over a limited range of section for any particular frequency band.

The theory of the effect is examined for circular-section conductors. It is shown that in all self-supporting helical coils suitable for short-wave work, where the conductor radius is greater than 0·1 cm., the effect of change of current distribution with temperature-change is such that no appreciable increase of temperature-coefficient of inductance occurs. For coils wound with very fine wire the temperature-coefficient of inductance is not affected appreciably by change of current distribution. The effect of temperature on the current distribution and consequently on the coefficient of inductance is appreciable only when the conductor radius lies between the limits 0·001 and 0·2 cm. In such cases the coefficient has a component due to this effect which may be quite high over an appreciable frequency band. This condition occurs in practice with deposited or sprayed-on conductors. The temperature-coefficient of inductance of coils having a conductor section within the defined range reaches a maximum value at a particular frequency and is less at frequencies above and below this value.

Experimental verification is given of the conclusion arrived at in the theoretical discussion, together with an explanation of the behaviour of certain coils having ceramic formers. The conclusions arrived at from a study of such coils are applied to the design of coils suitable for use at high radio frequencies, and it is shown that the best type of construction from the point of view of electrical stability is one in which the radial thickness of the conductor is small compared with the radius of the turn while the axial spacing is large.

CONTENTS

CONTENTS—*continued*

(1) INTRODUCTION

In a previous paper† observed values of the temperature-coefficient of inductance of a number of coils have been tabulated‡ and an explanation has been given of the properties of such coils in terms of the mechanical deformation which occurs with variation of temperature. Nearly all the coils considered in this work had conductors of appreciable area of cross-section. More recently the behaviour of coils with conductors of very small cross-section has been studied and it has been found that the change of inductance with temperature is considerably greater than the theoretical value corresponding to the mechanical changes which occur. It has also been observed that the temperature-coefficient of inductance is a function of frequency, a property which appears to be peculiar to coils having certain shapes and sizes of conductor section.

One object of this paper is to present the data obtained on such inductance coils and to show that the observed behaviour is consistent with a theory involving the distribution of the radio-frequency current in the conductor section. A further object is to show what types of coil are liable to exhibit this phenomenon to a marked degree and what types of construction should be avoided if a high stability of inductance with respect to temperature is desired.

Although evidence of a variation of the temperature coefficient of inductance with frequency has been obtained from tests made on a number of coils wound with copper wire of small circular section, the most notable case of this phenomenon was obtained with a coil consisting of a copper conductor deposited on a ceramic former. The variation with frequency of the temperature-coefficient of inductance of this coil is plotted in Fig. 1 (curve marked "observed coefficient"). It will be noticed that the coefficient at a frequency of 10 Mc./sec. is about five times as great as the value at low frequencies. The properties of this coil were found to be so unusual that it was considered advisable to make a very careful analysis of the various factors which might conceivably be responsible for this anomalous behaviour.

* Official communication from the National Physical Laboratory.

† H. A. THOMAS: "The Stability of Inductance Coils for Radio Frequencies," *Journal I.E.E.*, 1935, vol. 77, p. 702.

‡ *Loc. cit.*, Table 1.

(2) DISCUSSION OF OBSERVATIONS OF THE TEMPERATURE-COEFFICIENT OF INDUCTANCE OF A CERAMIC-FORMER COIL

The mechanical dimensions of this particular coil were as follows:—

Diameter	6 cm.
Number of turns	18
Ratio: Length/diameter ..	2 (approx.)
Axial spacing between turns	0·4 cm.

The electrical constants were:—

Inductance	$= 11\cdot4\ \mu$H
Self-capacitance	$= 2\cdot2\ \mu\mu$F
Resistance	$= 0\cdot35$ ohm
Natural frequency ..	$= 31\cdot7$ Mc./sec.
Permittivity of ceramic former	$= 6\cdot5$
Temperature-coefficient of permittivity of former material .. .. (σ)	$= +\ 160 \times 10^{-6}$ per deg. C.
Expansion coefficient of former material.. (α)	$= +\ 7\cdot8 \times 10^{-6}$ per deg. C.

The section of the deposited conductor is shown in Fig. 1. It is impossible to measure directly the thickness of this deposit but, if it is assumed to be uniform and to have the normal conductivity of copper, the thickness can be calculated from the measured d.c. resistance. The value obtained on these assumptions is 0·0275 mm. and can be taken as an approximation to the actual value; the thickness is probably not constant over the whole conductor length.

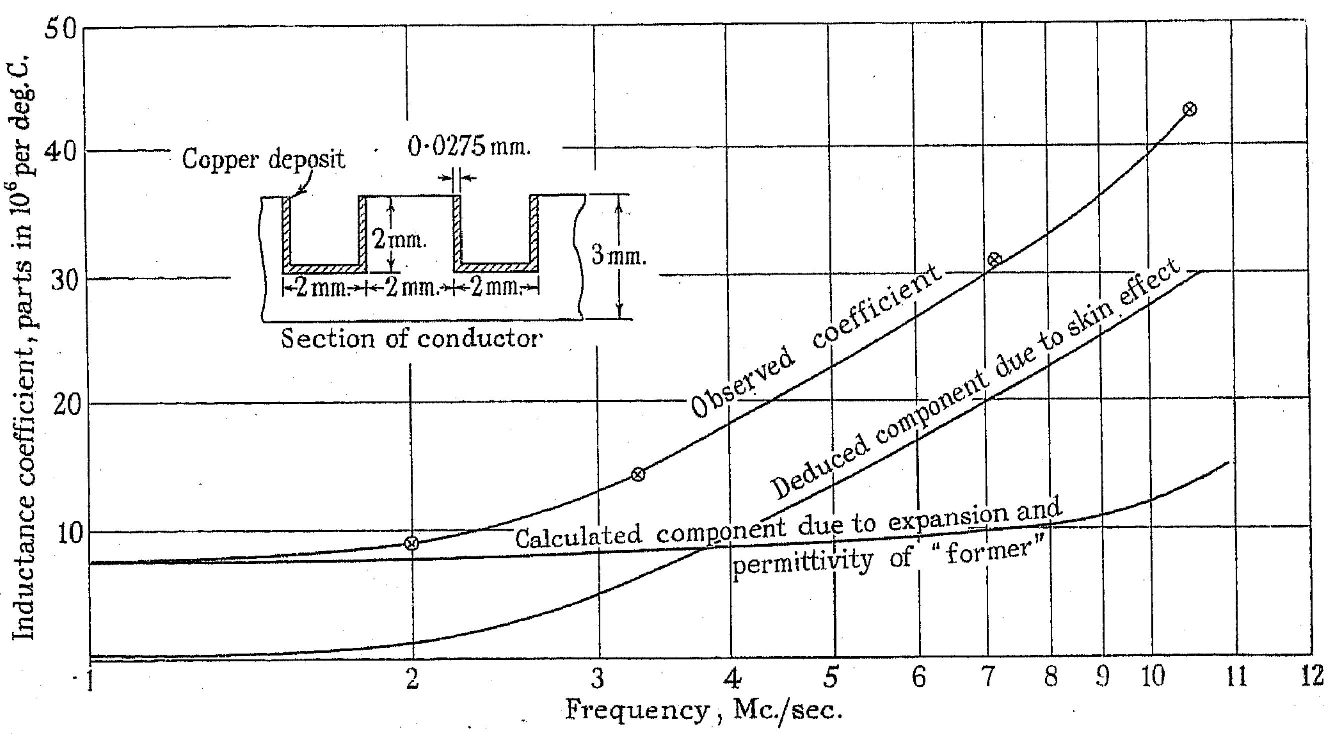


Fig. 1.—Analysis of components of inductance coefficient of ceramic-former coil.

(a) Effects attributable to Change of Self-capacitance with Temperature

Howe's empirical formula for self-capacitance gives $C = 0\cdot64r\ \mu\mu$F for an air-spaced coil in which the length is twice the diameter and r is the radius of the coil in centimetres. For the coil now being considered the theoretical value of the self-capacitance, for an air dielectric, is $1\cdot92\ \mu\mu$F. Measurements of the natural frequency of this coil, together with audio-frequency bridge measurements, have shown that the actual self-capacitance is $2\cdot2\ \mu\mu$F; the difference between this and the theoretical value is presumably attributable to the permittivity of the " former."

Table 1

Self-Capacitance Components of Ceramic-Former Coil

Values of self-capacitance components	Micro-micro-farads	Percentage of total capacitance
Self-capacitance to earth ..	1·56	71
Mutual capacitance of turns	0·64	29
Total self-capacitance ..	2·20	100

Now it can be assumed for the purpose of an approximate explanation that the self-capacitance has two components, one due to the electric flux within the solid dielectric and the other due to the flux from the turns to earth through the air dielectric. For the purpose of computing the first component it can be assumed that the electric flux between two adjacent turns for the particular conductor section shown in Fig. 1 is confined to the solid dielectric, and that the electric field density is uniform. Furthermore, if it is assumed that the current at all points in the coil is the same, then it can readily be shown that the value of the capacitance component due to the solid dielectric is $0\cdot64\ \mu\mu$F. This means that the remaining $1\cdot56\ \mu\mu$F is due to the surrounding electric field to earth. The actual and percentage values of the two components of the self-capacitance are given in Table 1. If the ceramic former were removed, the mutual capacitance of the turns would be reduced from

$0 \cdot 64\ \mu\mu F$ to $0 \cdot 094\ \mu\mu F$ and the total capacitance would be $1 \cdot 66\ \mu\mu F$. The presence of the "former" therefore increases the self-capacitance by only 33 %.

It is interesting to compare this result with certain measurements given by Jackson* in which it is shown that the increase of capacitance due to the presence of a paxolin former is only 23 %. The permittivities of paxolin and of the ceramic former used in these tests are about 4 and $6 \cdot 5$ respectively. Jackson's results suggest, therefore, that the increase of self-capacitance due to the ceramic former should be $23 \times 6 \cdot 5/4$ or 37 %. The agreement between this experimental result and the previously calculated effect of the solid dielectric is noteworthy. It is quite clear from these measurements that the self-capacitance is only affected to a slight degree by the presence and nature of the "former" material.

The temperature-coefficient of frequency of an oscillation circuit in which the tuning capacitance is independent of temperature is given by the following expression:—

$$\frac{\Delta f}{f} = \tfrac{1}{2}\left[\alpha + \sigma\left(\frac{C_s}{C + C_s}\right)\right] \quad . \quad . \quad . \quad (1)$$

in which α = expansion coefficient of "former" ($7 \cdot 8 \times 10^{-6}$ per deg. C. in this case),

σ = temperature-coefficient of permittivity of "former" ($+ 160 \times 10^{-6}$ per deg. C. in this case),

C_s = capacitance due to permittivity of "former,"

C = sum of all other capacitances not affected by temperature.

In the particular case of the ceramic-former coil $C_s = 0 \cdot 64\ \mu\mu F$ and C is an inverse function of frequency, its minimum value of $1 \cdot 56\ \mu\mu F$ occurring at the natural frequency of the coil. The temperature-coefficient of inductance due to expansion and change of permittivity of the "former" is plotted against frequency in Fig. 1, together with the inductance coefficient of the coil. It will be seen that there is a much greater rise in the temperature-coefficient of inductance than can apparently be explained by the mechanical or electrical changes in the "former." This conclusion was confirmed by measurements of the expansion coefficient, permittivity, and temperature coefficient of permittivity of the material of which the "former" was made.

The fact that the observed discrepancy between the measured and calculated values of the temperature-coefficient of inductance increases rapidly with frequency suggests a change of inductance with temperature-rise which is not due to alterations of shape.

(b) Effects attributable to Variation of Current Distribution with Temperature

It is well known that the increase of resistance of a conductor with temperature produces a re-distribution of the current flowing in the section. This will change the effective inductance, but this variation of current distribution with temperature has hitherto been considered to be of negligible importance. It is true that Groszkowski* has observed appreciable effects arising from this cause in the case of certain coils of rather unusual construction, but if the part of the temperature-coefficient of inductance which is due to change of conductor resistance with temperature is calculated for any normally-wound short-wave coil it will be found that it is exceedingly small. For example, the results of measurement on a former-less coil of large conductor section are given in Table 2. This particular coil consisted of 8 turns of copper wire of circular cross-section wound helically, the radius of the wire being $0 \cdot 32$ cm., the diameter of the coil $8 \cdot 4$ cm., and the turn spacing $0 \cdot 84$ cm.

Table 2

EXPERIMENTAL RESULTS ON FORMER-LESS COIL

Frequency	Temperature-coefficient of inductance
kc./sec.	parts in 10^6
3 297	+ 7
11 518	+ 8
13 350	+ 12
18 062	+ 5

The results show that no increase in the coefficient of the nature and magnitude under consideration occurred over a large frequency range. It appeared, therefore, at this stage of the work that appreciable increase of temperature-coefficient of inductance with frequency was peculiar to coils of very small conductor sections.

An examination of the dependence of the temperature coefficient on frequency and cross-section has been made, from which it has been found that effects due to current redistribution with resistance-change are by no means unimportant in certain cases, although previous conclusions to the contrary were quite correct for the particular cases then considered. The nature of the effect is such that its influence on the temperature-coefficient of inductance may be very considerable when the conductor section becomes comparable with that of a deposited metallic film. The unique electrical feature of deposited coils is not the presence of the dielectric material but the fact that the section of the conductor lies within a critical range where changes of resistance due to temperature give rise to appreciable temperature-coefficients of inductance.

(3) THE EFFECT OF FREQUENCY VARIATION ON THE TEMPERATURE-COEFFICIENT OF INDUCTANCE OF STRAIGHT WIRES OF CIRCULAR CROSS-SECTION

The self-inductance of a conductor depends appreciably on the field within its cross-section; any deviation of the distribution of the current from uniformity always gives rise in practice to a decrease of inductance. The value of this decrease depends on the frequency of the current, on the size and shape of the cross-section of the conductor, and on the conductivity and permeability of the conductor. This decrease of inductance is always accom-

* W. JACKSON: "The Self-Capacitance of Single-Layer Coils," *Philosophical Magazine*, 1935, vol. 19, p. 823 (see Table 3).

* J. GROSZKOWSKI: "The Temperature Coefficient of Inductance," *Proceedings of the Institute of Radio Engineers*, 1937, vol. 25, p. 448.

panied by an increase in resistance of the conductor. The inductance approaches a limiting value with increasing frequency, whereas the resistance increases indefinitely. Unfortunately, the rigorous solution of the problem at high frequencies for the various cases for which the inductance with steady currents may be calculated is in many instances very difficult, if not impossible. Some of the simpler cases, however, have received attention, with the result that the changes of inductance and resistance may be calculated with reasonable accuracy.

Formulae for calculating the change of inductance as a function of frequency for straight cylindrical wires, two parallel wires, and circular rings of circular section, have been given by Rosa and Grover.* For a straight cylindrical wire,

$$\frac{\Delta L}{L} = -\frac{\left(1 - \frac{4}{x}\cdot\frac{Z}{Y}\right)}{\left(4\log\frac{2l}{\rho}\right) - 3} \quad . \quad . \quad . \quad (2)$$

in which ΔL = change of inductance at frequency f,
L = d.c. value of inductance,

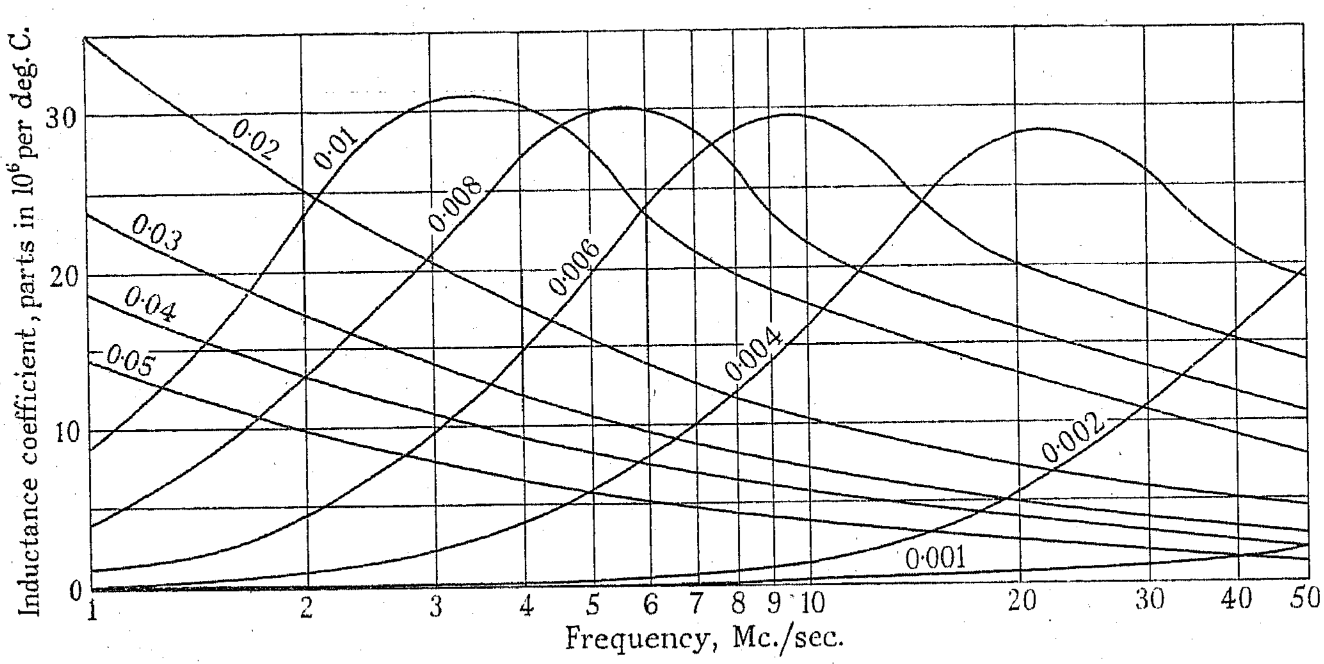


Fig. 2.—Dependence of inductance coefficient of straight copper wire on conductor radius and frequency.
l = 320 cm.

l = length of conductor in cm.,
ρ = radius of conductor in cm.,
$x = 2\rho\sqrt{\left(\frac{\pi p\mu}{\sigma}\right)}$,
σ = specific resistance of conductor (1 722 e.m.u. at 20° C. for copper),
μ = permeability of conductor,
f = frequency = $p/(2\pi)$,
Z/Y = a function of x.

The functions Y and Z are given as

$$Y = (\text{ber}'\,x)^2 + (\text{bei}'\,x)^2$$

and $$Z = \text{ber}\,x\ \text{ber}'\,x + \text{bei}\,x\ \text{bei}'\,x$$

where ber x and bei x are functions introduced by Kelvin, being respectively the real and imaginary parts of the Bessel function of order zero, J_0, having for its argument $xj\sqrt{j}$, where x is a real quantity and $j = \sqrt{-1}$.

These functions are given by the series

$$\text{ber}\,x = 1 - \frac{x^4}{2^2 . 4^2} + \frac{x^8}{2^2 . 4^2 . 6^2 . 8^2} \cdots$$

$$\text{bei}\,x = \frac{x^2}{2^2} - \frac{x^6}{2^2 . 4^2 . 6^2} + \frac{x^{10}}{2^2 . 4^2 . 6^2 . 8^2 . 10^2} \cdots$$

and ber′ x and bei′ x are their differential coefficients with respect to x.

The values of Y and Z have been evaluated and are given in Table 22 of Rosa and Grover's paper.*

The limiting value of the change of inductance is

$$\left(\frac{\Delta L}{L}\right)_{x=\infty} = -\frac{1}{4\log(2l/\rho) - 3} \quad . \quad . \quad . \quad (3)$$

and since

$$L_{x=0} = 2l\left[\log\frac{2l}{\rho} - 1 + \frac{\mu}{4}\right]$$

$$= 2l\left[\log\frac{2l}{\rho} - \frac{3}{4}\right] \quad \text{for copper}$$

$$(\Delta L)_{x=\infty} = -l/2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Thus the decrease of inductance (in centimetres) when the frequency is indefinitely increased is equal to half the length of wire (in centimetres) and is independent of the area of cross-section. The change of inductance is a function of the quantity:—

$$x = 2\rho\sqrt{\left(\frac{\pi p\mu}{\sigma}\right)} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$= 0\cdot2142\rho\sqrt{f} \quad \text{for copper at 20° C.}$$

By using Table 22 in Rosa and Grover's paper to obtain the variation of the function $\left(\frac{4}{x}\cdot\frac{Z}{Y}\right)$ for small changes of x and then determining the temperature-change required to produce this same change of x over a band of frequencies, it is possible to obtain the component of the temperature-coefficient of inductance due to the re-distribution of current over the circular cross-section. The

* "Formulae and Tables for the Calculation of Mutual- and Self-Inductance," *Bulletin of the Bureau of Standards*, 1912, vol. 8, p. 1.

* *Loc. cit.*

results of this analysis for wires of varying radius and a constant length of 320 cm. are shown in graphical form in Fig. 2, the radius in centimetres being stated for each curve. For shorter lengths, the temperature-coefficient of inductance is increased by the multipliers shown in Table 3, the form of the curve remaining unchanged in each case.

Table 3

INDUCTANCE-COEFFICIENT MULTIPLIERS FOR VARIOUS LENGTHS OF WIRE

Length of conductor (cm.)	Radius of wire (cm.)									
	0·001	0·002	0·004	0·006	0·008	0·01	0·02	0·03	0·04	0·05
10	1·38	1·41	1·45	1·47	1·49	1·51	1·57	1·60	1·64	1·67
20	1·29	1·30	1·33	1·34	1·36	1·37	1·41	1·43	1·45	1·47
40	1·20	1·21	1·23	1·23	1·24	1·25	1·28	1·29	1·31	1·32
80	1·13	1·13	1·14	1·14	1·15	1·15	1·17	1·18	1·18	1·19
160	1·06	1·06	1·07	1·07	1·07	1·07	1·08	1·08	1·08	1·09
320	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1·00

Table 3 shows that values of the temperature-coefficient of inductance derived from Fig. 2 are modified only slightly by appreciable changes in the length of conductor. When applying the results of this analysis to all ordinary shapes and sizes of single-layer coils it will be found that the " proximity " effect is not usually very appreciable, except in cases where adjacent turns are nearly in contact; the " straight-wire skin-effect " components plotted in Fig. 2 are rarely increased by more than 20 %.

An examination of Fig. 2 shows that the temperature-coefficient of inductance due to change of resistance is quite large over a rather limited range of both conductor radius and frequency. A maximum value of this coefficient occurs at a definite frequency for each size of conductor, the value decreasing very slightly with decreasing radius. The frequency at which this practically constant coefficient is obtained decreases as the radius of the conductor is increased, with the result that over any particular frequency band there is some corresponding range of conductor size which gives appreciable values of the temperature-coefficient of inductance. The maximum values of the coefficient of inductance together with the frequencies at which they occur are given in Table 4 for circular-section conductors of various sizes.

These maximum values of the temperature-coefficient of inductance all occur when x equals 3·85, which means that the rate of change of inductance is a maximum for this particular value of x. The existence of such a maximum value can be anticipated on physical grounds. At low frequencies, with nearly uniform current distribution, the rate of change of inductance with resistance variation is small; at infinite frequency, with wholly peripheral current distribution, it is asymptotically zero. It is obvious, therefore, that it reaches a maximum at some intermediate frequency. With wires of large diameter, this particular distributional condition exists at a comparatively low frequency, and consequently at high radio frequencies the self-inductance is approaching its limiting upper value. With wires of small diameter, however, this particular distributional condition occurs at a very high frequency and consequently over the normal radio-frequency band the inductance does not change appreciably from its steady-current value.

Table 4

MAXIMUM VALUES OF TEMPERATURE-COEFFICIENT OF INDUCTANCE OF CIRCULAR-SECTION STRAIGHT COPPER WIRES

Radius of conductor (l = 320 cm.)	Maximum value of inductance coefficient	Frequency at which maximum value occurs
cm.	parts in 10^6	(Mc./sec.)
0·001	25·2	322
0·002	26·5	80·5
0·004	28·2	20·2
0·006	29·4	8·95
0·008	30·0	5·05
0·01	30·8	3·22
0·02	32·8	0·81
0·03	34·2	0·358
0·04	35·5	0·202
0·05	36·4	0·129
0·10	39·5	0·032

Referring to Fig. 2, it is seen that appreciable temperature-coefficients of inductance may occur within the radio-frequency range 1 to 50 Mc./sec. if the radius of the wire lies between 0·001 and 0·10 cm., corresponding approximately to 50 S.W.G. and 14 S.W.G. respectively.

(4) EXPERIMENTAL VERIFICATION OF THE DEPENDENCE ON FREQUENCY OF THE TEMPERATURE-COEFFICIENT OF INDUCTANCE OF COILS

(a) Experiments with a Coil on a Grooved-Silica Former

In view of the fact that within the frequency range 1 to 20 Mc./sec. the temperature-coefficient of inductance may be appeciable only for wires of small diameter, it is necessary in conducting experiments on such coils to ensure that the dimensions of the "former" shall be sensibly independent of temperature and that the method of winding shall be such as to give very precise location of the fine-wire conductor. For this purpose a silica tube was used to support the wire, the outer and inner radii of this tube being 6·7 and 5·6 cm. respectively; a spiral groove was cut on this tube with a pitch of 0·5 cm., and a coil of 8 turns was wound on to this former. The inductance of the coil so formed was about 5·4 μH.

The temperature-coefficient of inductance was measured over a band of frequencies for three wire sizes, viz. No. 40 S.W.G. (0·0061 cm. radius), No. 38 S.W.G. (0·0076 cm. radius), and No. 36 S.W.G. (0·0096 cm. radius). In each case bare copper wire was used, wound under slight tension.

The experimental results obtained are plotted against frequency in Figs. 3, 4, and 5, for the above-mentioned three gauges. Although the accuracy of repeat observations at any particular frequency is not high, there appears to be definite evidence of a frequency effect. For instance, the form of the curve shown in Fig. 3 is essentially different from that shown in Fig. 5. The coefficients plotted are the total values due to expansion and skin effect. It has been shown previously* that the component of the temperature coefficient of inductance due to expansion alone for a coil of this type may be expected to be about half the temperature coefficient of expansion of the wire. Consequently in this case a positive temperature-coefficient of inductance of about 9 parts in 1 million can be attributed to the coil at frequencies well removed from the range where skin-effect phenomena are of significance. Subtracting this value of 9 parts in 1 million from the experimental results plotted in Figs. 3, 4, and 5, quite good agreement is obtained between the observed and the calculated coefficient due to variation of current distribution with temperature-change.

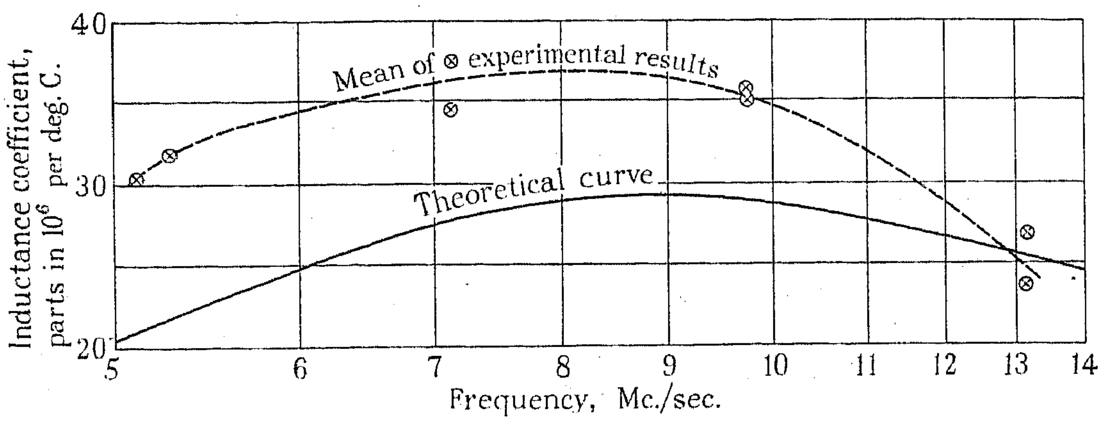


Fig. 3

Radius of conductor, 0·0061 cm. (No. 40 S.W.G.).

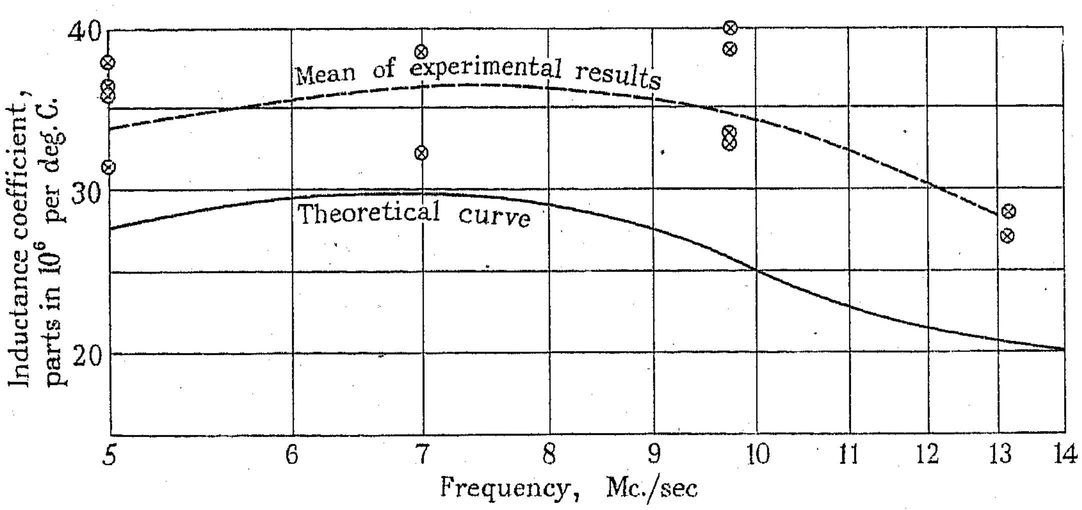


Fig. 4

Radius of conductor, 0·0076 cm. (No. 38 S.W.G.).

(b) Experiments with a Skeleton-Former Coil

In the previous case the conductor was in close contact with the former. It was considered advisable to repeat the measurements, using a coil in which the conductor was supported on a skeleton former. For this purpose a silica tube was used of the same dimensions as before, six

* H. A. THOMAS: "The Stability of Inductance Coils for Radio Frequencies," *Journal I.E.E.*, 1935, vol. 77, p. 708. (See Coil F in Table 1 of this paper.)

thin glass plates were cemented to the outside, and grooves were cut in these plates to locate the wire. In this way a hexagonally-shaped winding of 8 turns was wound on a former of negligible expansion coefficient. The coil so formed had a circumscribed diameter of 8·6 cm. and a turn spacing of 0·5 cm.

Using a winding of No. 34 S.W.G. (0·0117 cm. radius) copper wire, the temperature-coefficient of inductance was measured at a frequency of 4·1 Mc./sec., and was found to be + 97·5 parts in 1 million per deg. C. Several check measurements were made at the same frequency, and in all cases agreement to within 5 % was obtained. The wire was now removed from the former and rewound; the inductance coefficient was found to be + 5·4 parts in 1 million per deg. C.; a second rewind gave a value of + 17 parts in 1 million per deg. C.

It is apparent from these results that the coefficient of a lightly-supported fine-wire coil may lie between wide limits, but for any particular winding very good agreement between successive results was always obtained and, furthermore, slight mechanical vibration did not affect the behaviour. It seemed probable that the various observed coefficients for the same wire and former could only be produced by a different set of winding stresses, which would in turn give rise to different forms of mechanical distortion on heating. If this were the case, variation of frequency should change the coefficient by the amount calculated for skin-effect alone.

With the object of demonstrating whether this took place the temperature-coefficient of inductance was measured at a number of frequencies over the band 1 to 10 Mc./sec. The results are shown in Fig. 6, from which it is seen that good agreement was obtained with theory. In this case—the third rewind—the coefficient attained a maximum value of 130 parts in 1 million per deg. C. The coil was now wound with No. 26 S.W.G. (0·0228 cm.

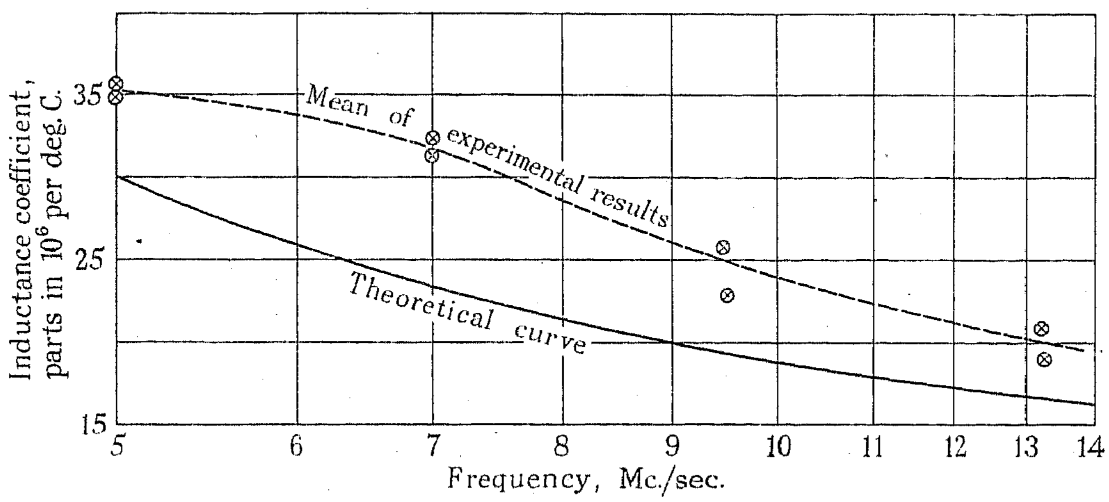


Fig. 5
Radius of conductor, 0·0096 cm. (No. 36 S.W.G.).

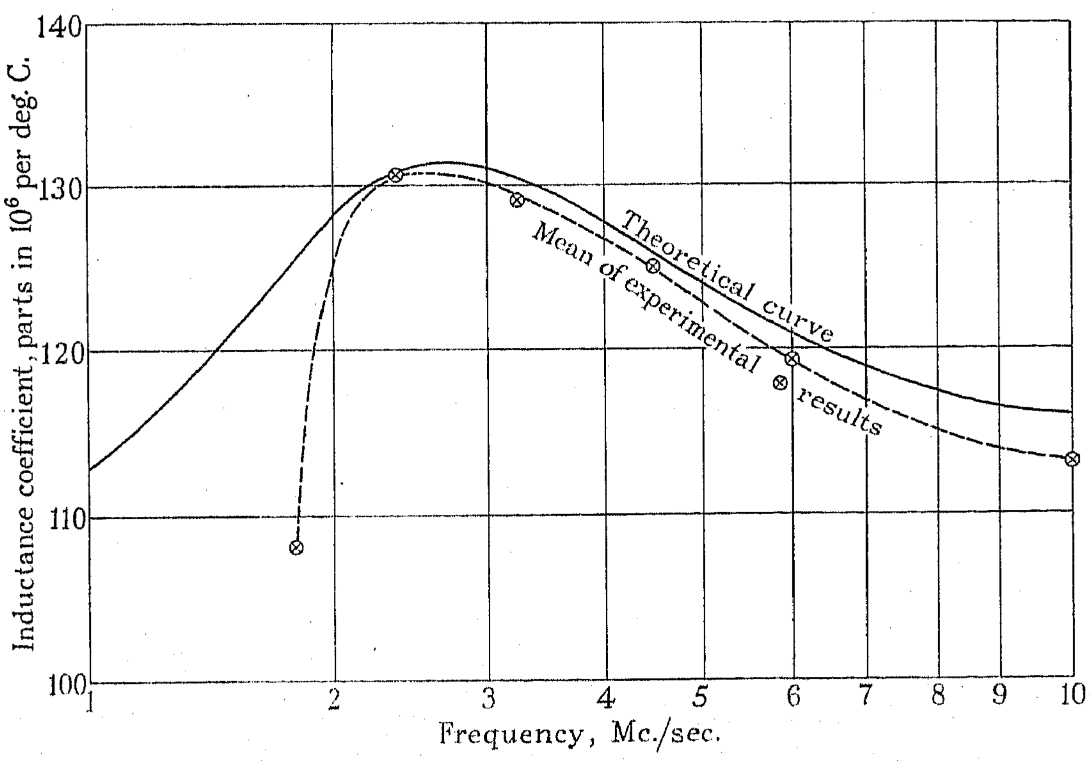


Fig. 6
Radius of conductor, 0·0117 cm. (No. 34 S.W.G.).

radius) copper wire and measurements were made over the same frequency range. The results plotted in Fig. 7 show that in this case no maximum value was obtained at a particular frequency. The agreement with the theoretical curve for this wire size is not so good as in the other cases, the curve showing only a slight rise in coefficient with fall of frequency.

(c) Conclusions from Experiments on Fine-Wire Coils

The experiments described above furnish evidence in support of the theory given in Section (3). In the case of a coil consisting of a fine wire tightly wound on a former which rigidly fixes its position at all points, the temperature-coefficient of inductance has two components. One component (i) is equal approximately to the mean value of the expansion coefficients of the metal and the former, and is equal approximately to the calculated coefficient of a straight wire of the same size due to current redistribution with change of resistance.

When the fine wire is not completely constrained by the former but is located only at a few points, the temperature coefficient is again made up of two components, (ii) being the same as before. Component (i) is, however, incalculable since it appears to be caused by the unknown stress distribution in the wire due to winding. It should be noted that in such a coil a large portion of the wire is stressed beyond the elastic limit, which condition is known to be a fruitful source of abnormal distortions. Furthermore, it is well known that a hexagonal coil cannot be wound with the conductor under considerable stress except in the case of very fine wires, and general observation of such skeleton-former coils when heated shows that the relative movement between turns is very large and quite indeterminate.

It is clear that whereas a coil fully supported on a good former has a low temperature-coefficient of inductance which is calculable, a partially-supported coil is definitely unsuitable if constancy of inductance and a low temperature-coefficient of inductance is desired.

(5) APPLICATION OF THE THEORY TO THE DETERMINATION OF THE TEMPERATURE-COEFFICIENT OF INDUCTANCE OF COILS

(a) General

The theory of the variation of inductance with frequency for straight wires of circular section is applicable to coils within fairly well-defined limits. The variation of inductance of a coil with frequency is due partly to the change of self-inductance of the circular turns and partly to the change of mutual inductance between turns. Reference to Table 23 of Rosa and Grover's paper* shows that if a straight-wire conductor is bent into the form of a circular ring the fractional change of inductance with frequency is increased from the straight-wire value by an amount which rarely exceeds 20 % for most practical shapes and is usually much less. The change of mutual inductance between turns depends upon the diameter of the wire and the spacing of the turns, and for closely-wound coils in which the mutual inductance forms an appreciable part of the total inductance it is found that the temperature-coefficient of inductance of the coil is about double the straight-wire value. For self-supporting coils in which the spacing between turns is appreciable the effect of the mutual inductance between turns is not so large.

In general, the values of the temperature-coefficient of inductance plotted in Fig. 2 can be considered to represent approximately the performance of most short-wave coils using circular-section conductors. These values are strictly valid for coils of small conductor cross-sectional area and large turn spacing: for closely-wound coils of

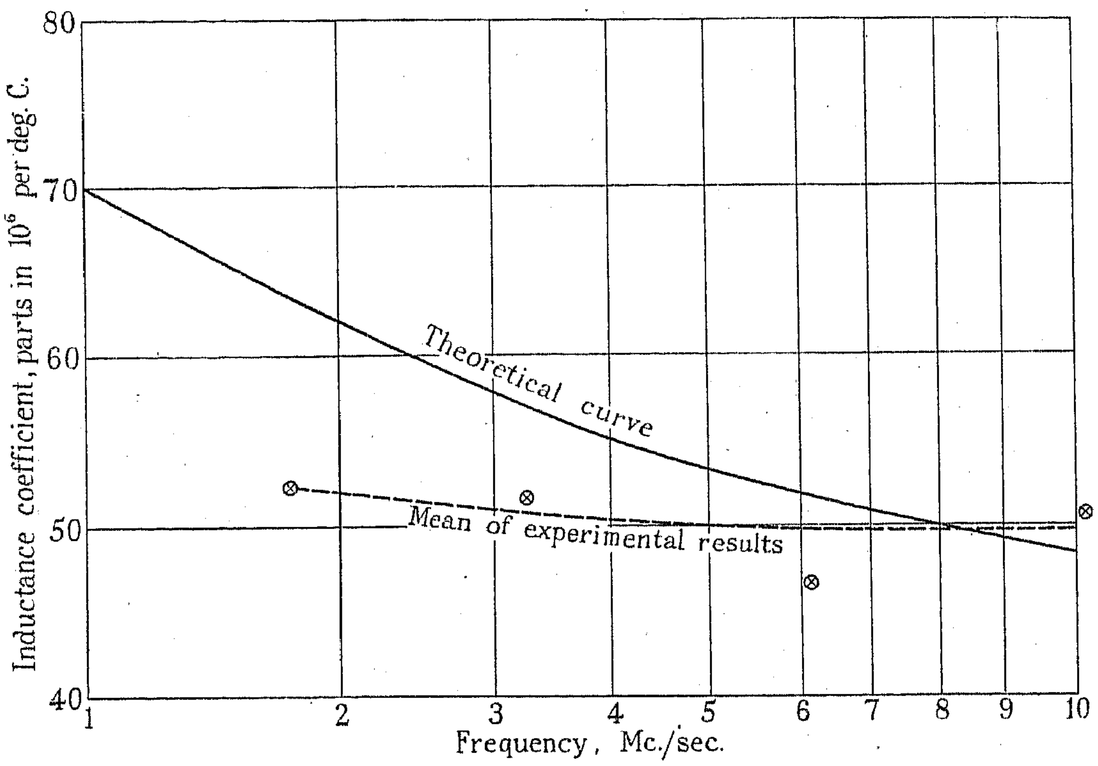


Fig. 7
Radius of conductor, 0·0228 cm. (No. 26 S.W.G.).

* *Loc. cit.*

large conductor cross-section, the temperature-coefficient of inductance may be as high as $2\frac{1}{2}$ times the values given, but such cases are unusual.

(b) Coils having an Appreciable Radial Depth of Section

In the case of the coil discussed in Section (2), exact computation of the current distribution at radio frequencies for the U-shaped section illustrated in Fig. 1 is impossible, but it can be seen in general terms that, as the frequency increases, the current density will increase at the inner surface of the strip base of the conductor and will diminish up the side walls. Consequently the shift of the mean current axis at infinite frequency will be greater than one-half the thickness of the deposit.

The equivalent circular section to give the same d.c. resistance has a diameter of 0·46 mm., and the calculated temperature-coefficient of inductance of this equivalent section is shown in Fig. 8 together with the observed characteristic for the U-shaped section. The ratio of the effective radio-frequency resistance to the d.c. resistance (R_e/R_0) is also plotted for the same two cases in Fig. 9. It is seen that the use of the U-shaped section has reduced the effective resistance quite appreciably and has reduced the temperature-coefficient of inductance over a large frequency range. The rise in coefficient above a frequency of 3 Mc./sec. is due probably to the shift of the mean current axis; it should be noted, however, that the form of the variation of the temperature-coefficient of inductance with frequency differs from that of a circular-section conductor of the same area owing to the difference between the nature of the current redistribution with frequency-change.

If the depth of the conductor section in a plane perpendicular to the axis of the coil is an appreciable fraction of the coil radius, it is no longer justifiable to calculate the maximum change of inductance on the basis of subtracting the flux within the section from the flux within the coil, thus assuming at very high frequencies that the current is distributed uniformly within an infinitely thin layer bounding the conductor section. If it is assumed for a closer approximation of the actual current distribution at high frequencies that the current is concentrated on the inner edge of the conductor section, then the fractional change of inductance will be approximately equal to half the radial depth of section divided by the mean radius of the turn; in the case of the ceramic-former coil already referred to, this is 3·3 %. If, however, it is assumed that the current at high radio frequencies is concentrated within an infinitely thin layer uniformly bounding the U-shaped conductor section, the calculated change of inductance will be much less than 1 %.

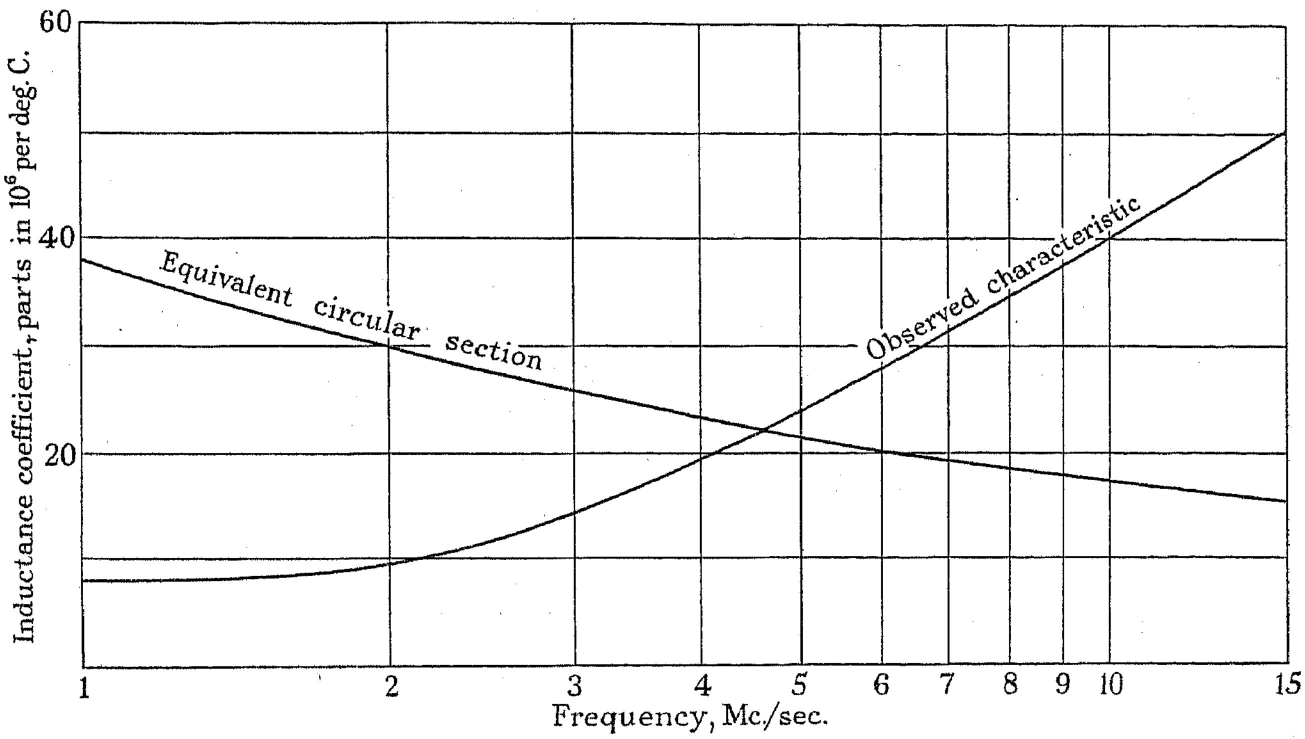


Fig. 8.—Characteristics of U-section coil.

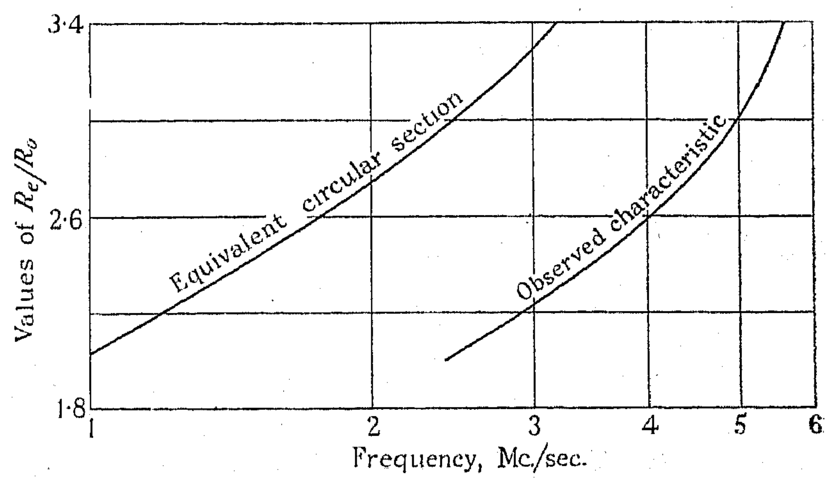


Fig. 9.—Characteristics of U-section coil.

With the object of obtaining further data on coils having a large radial depth of section, a coil was made of 12 turns of edge-wound copper strip 0·0315 cm. wide; the internal and external radii of the coil were 3·75 and 5·05 cm. respectively, and the turn spacing was 1 cm. The measured inductance at 500, 1 000, and 2 000 cycles

per sec., was 7·04 μH and may be regarded as the low-frequency value. Over the range of radio frequencies 1·8 to 3·9 Mc./sec. the inductance was 6·58 μH; the self-capacitance was 2·81 $\mu\mu$F and the natural frequency of the coil was 37·01 Mc./sec. The reduction of inductance from low to high frequencies is therefore 6·6 %, whereas the ratio of half the depth of the section to the mean radius is 14·7 %; in this case the inductance change from low to high frequency is very nearly equal to half the ratio of the radial depth of the conductor to the mean turn radius.

Table 5

	Coil 1	Coil 2
Number of turns	29·5	34·5
Thickness of conductor	0·16 cm.	0·16 cm.
Axial turn spacing	0·16 cm.	0·16 cm.
Inner radius	18·7 cm.	18·7 cm.
Outer radius	22·5 cm.	21·3 cm.
Observed change of inductance	7·8 %	7·3 %
Ratio: $\frac{\frac{1}{2}(\text{Conductor width})}{\text{Mean radius}}$	9·2 %	6·5 %

Another somewhat similar case is given by Morecroft.* The inductance of two edge-wound ribbon coils was measured over the frequency range 0·043 to 150 kc./sec., the results obtained and details of dimensions being given in Table 5.

In these tests the change of inductance is also very nearly equal to the ratio of half the conductor width to the mean radius.

It is evident from the results of measurement that the change of inductance with frequency may be quite large in those cases where the radial depth of the conductor section is appreciable; this will apply to flat ribbon conductors wound edgewise, or to U-shaped sections. If this effect is to be made small the radial depth must be reduced. In the case of the ceramic-former coil described this means that the walls of the section should be removed, since strip wound flatwise should show little trace of this effect.

(c) Coils wound with flatwise strip conductors

In accordance with the previous conclusion, tests were made on two coils having flatwise strip conductors on a ceramic former. The details of the coils are given in Table 6.

The observed temperature-coefficient of inductance of

Table 6

	Coil A	Coil B
Diameter	30 mm.	30 mm.
Number of turns	23	18
Ratio: $\frac{\text{Length}}{\text{Diameter}}$	2·5	1·8
Width of section	2 mm.	1·5 mm.
Radial depth of section	0·0076 mm.	0·035 mm.
Axial turn spacing	3 mm.	3 mm.
Inductance	6·3 μH	4·8 μH
Self-capacitance	1·6 $\mu\mu$F	1·4 $\mu\mu$F
Resistance	2·4 Ω	0·57 Ω
Natural frequency	52 Mc./sec.	59 Mc./sec.
Permittivity of ceramic former	6·5	6·5
Temperature coefficient of permittivity of former material	$+ 160 \times 10^{-6}$ per deg. C.	$+ 160 \times 10^{-6}$ per deg. C.
Expansion coefficient of former material.	$+ 7{\cdot}8 \times 10^{-6}$ per deg. C.	$+ 7{\cdot}8 \times 10^{-6}$ per deg. C.
Diameter of equivalent circular-section to give same d.c. resistance	0·15 mm.	0·26 mm.

* "Principles of Radio Communication," 2nd ed., p. 195.

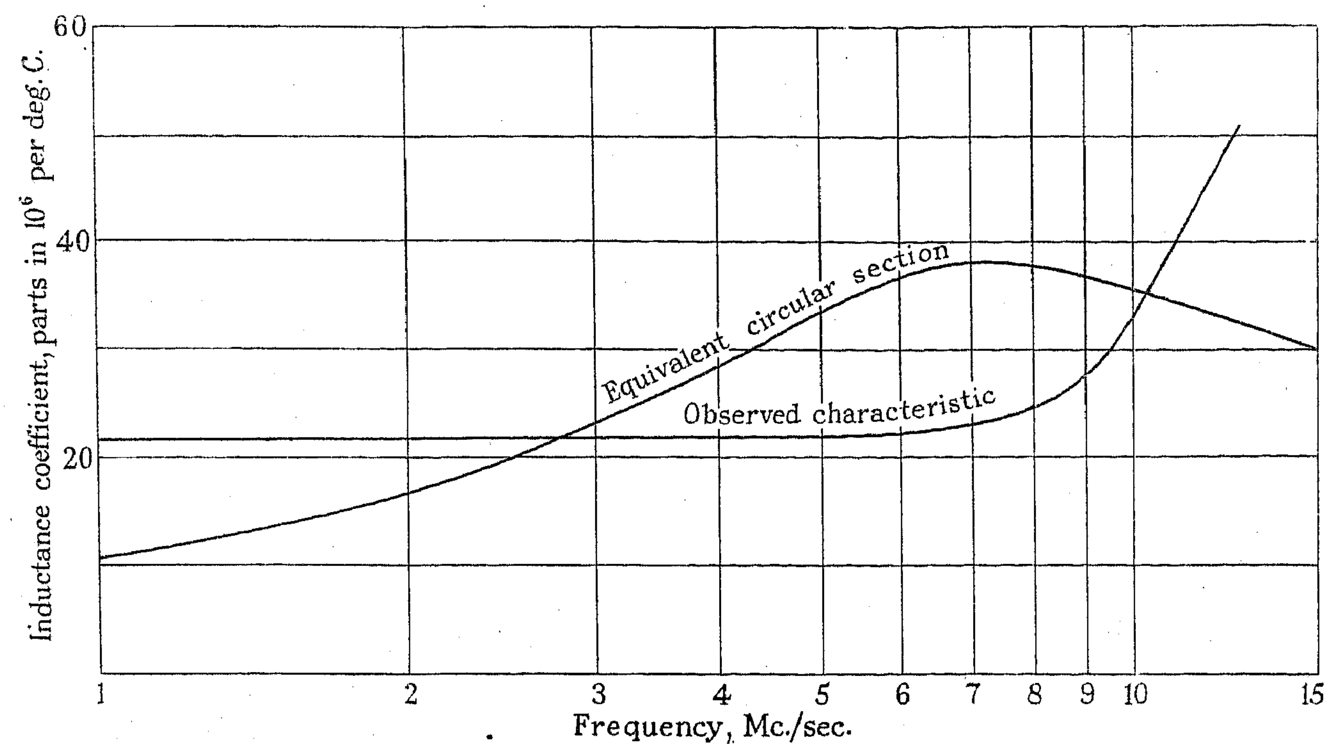


Fig. 10.—Characteristics of Coil A.

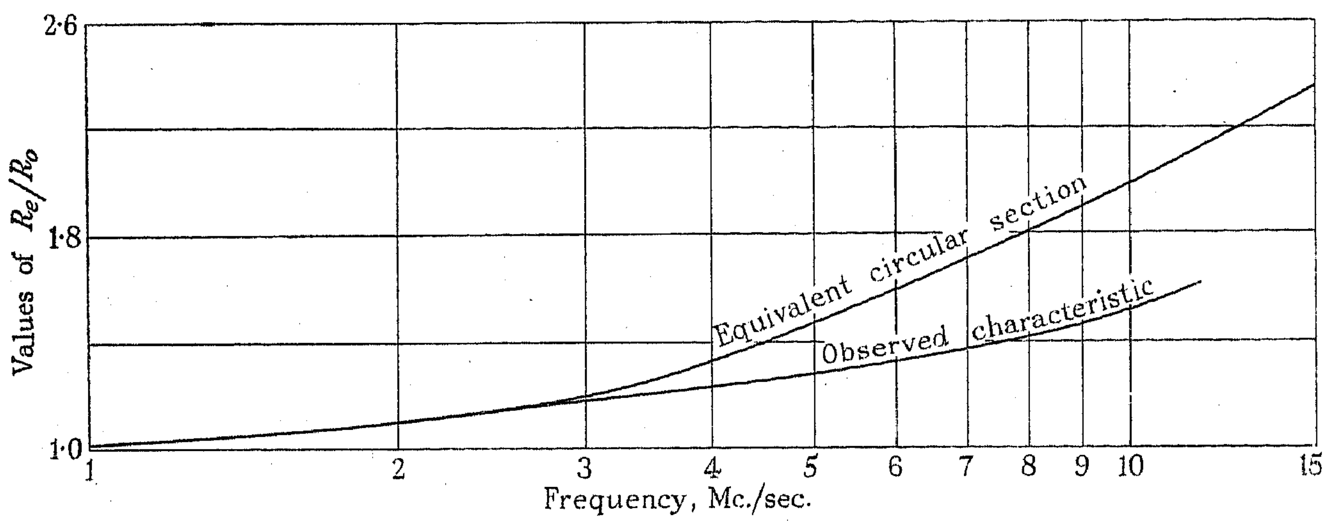


Fig. 11.—Characteristics of Coil A.

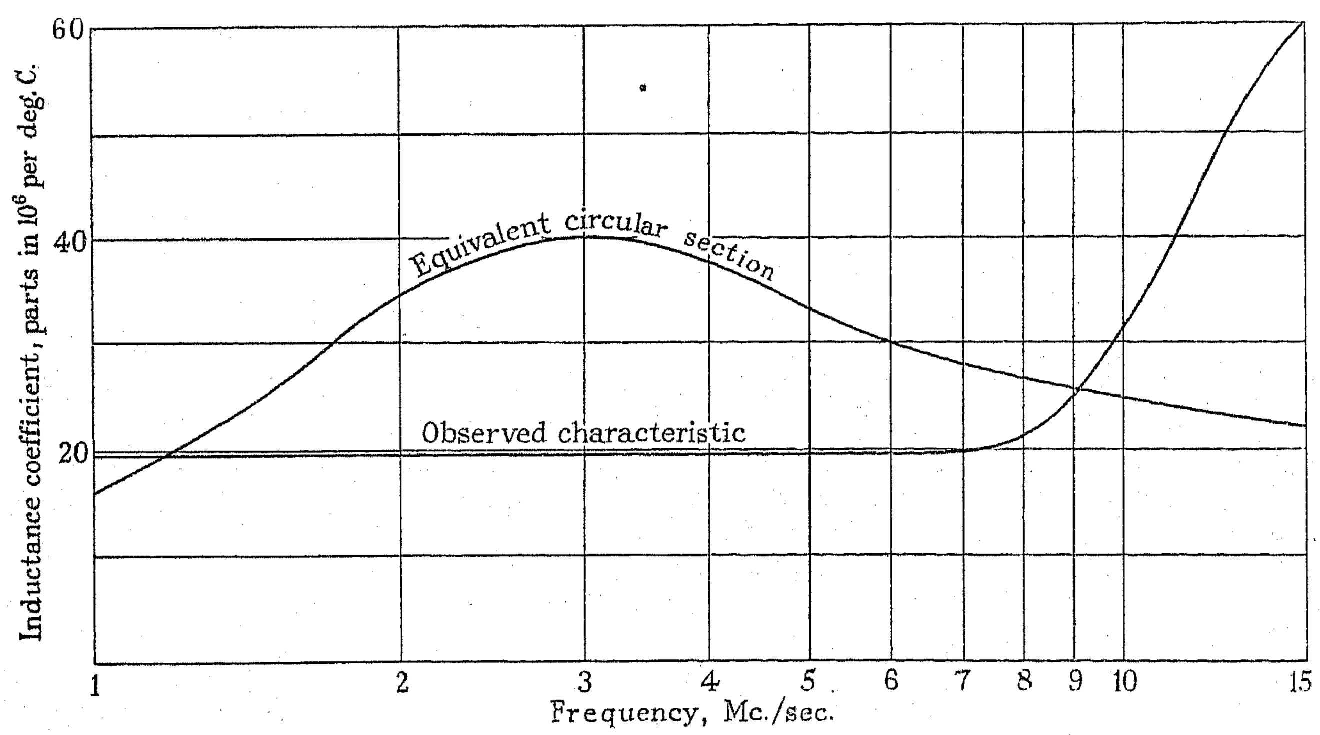


Fig. 12.—Characteristics of Coil B.

Coil A, together with the characteristic for the equivalent circular-section conductor, are plotted against frequency in Fig 10. The radio-frequency resistance characteristic is also plotted in Fig. 11.

It is seen that with such a very thin deposit (0·0076 mm.) the effective resistance increases very little with frequency and the temperature-coefficient of inductance remains constant up to a frequency of about 8 Mc./sec., above which frequency the coefficient appears to increase rapidly. Thus the adoption of the flat-ribbon section has effected a considerable improvement in the constancy of the temperature-coefficient of inductance with respect to frequency, but it is also apparent that a re-distribution of current occurs at the higher frequencies and produces a rapid increase of coefficient. This effect is probably due to the proximity of adjacent turns, the coefficient of the former material is less than 10 parts in 1 million. Approximate measurements have indicated that the expansion coefficient does not exceed this value.

It would appear from these results that to obtain a low temperature-coefficient of inductance which is sensibly independent of frequency, it is desirable to use a conductor of ribbon section deposited flatwise on a former of low temperature-coefficient of expansion. It is important that the turn spacing should be as large as possible, for then an appreciable current re-distribution can occur with frequency variation without producing an appreciable change of inductance. To establish this hypothesis it would be necessary to examine the properties of a number of coils in which the conductor sections were identical but in which the turn spacings were dissimilar. Unfortunately, it is not easy to repro-

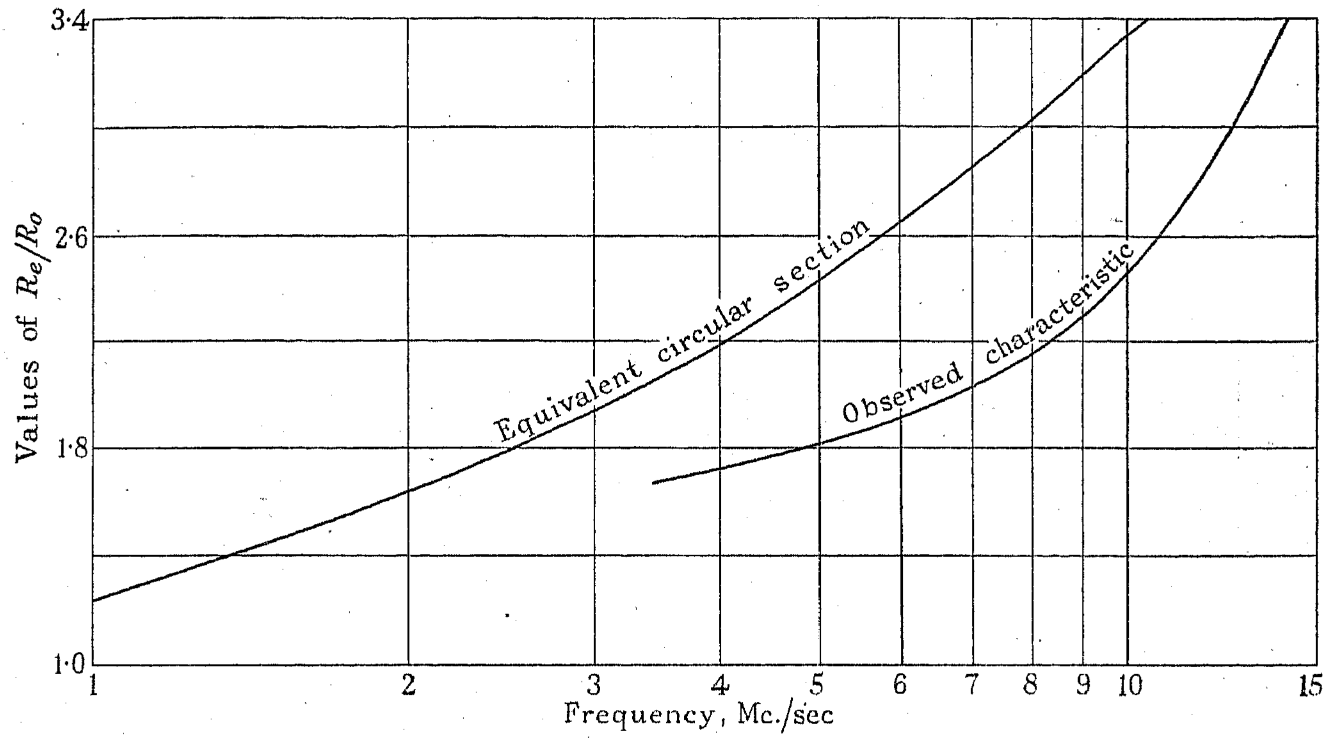


Fig. 13.—Characteristics of Coil B.

flux from which will tend to concentrate the current at the centre of the ribbon section and so reduce the mutual-inductance component.

The characteristics of Coil B are given in Figs. 12 and 13. In this case the deposit is considerably thicker (0·035 mm.) and the effective resistance increases with frequency to an appreciable extent, but owing to the larger turn spacing the inductance remains sensibly unchanged up to a frequency of about 8 Mc./sec., at which frequency the value of R_e/R_0 is 2·15. It appears, therefore, that a considerable increase of effective resistance can occur before the inductance value is affected, and that the mutual-inductance changes fairly rapidly thereafter owing to a change of current distribution; it is apparent from Fig. 13 that the form of the R_e/R_0 characteristic is essentially different from that of a circular-section conductor.

One unresolved point should be noticed, namely that the minimum value of the temperature-coefficient of inductance for both coils (A and B) is of the order of 20 parts in 1 million per deg. C., whereas the expansion duce a uniform deposit of known thickness in several coils by deposition methods, but it is hoped in the near future to obtain suitable coils by machining. The use of a ceramic former having a negligible coefficient of expansion is also obviously desirable.

(6) ACKNOWLEDGMENTS

The author wishes to acknowledge his indebtedness to the work of Prof. J. Groszkowski, which first called attention to the possible significance of the variation of current distribution with temperature as a factor in the variation of temperature-coefficient of inductance. He also wishes to place on record his indebtedness to Mr. F. M. Colebrook, B.Sc., for consultation in the course of the work, and to Messrs. A. C. Haxton, C. W. Spencer, B.Sc., and R. G. Chalmers, for assistance given in the experimental work.

The work described in this paper was carried out as part of the programme of the Radio Research Board and is published by permission of the Department of Scientific and Industrial Research.

SOME POLARIZATION PHENOMENA IN MAGNETIC MATERIALS, WITH SPECIAL REFERENCE TO NICKEL-IRON ALLOYS

By T. A. LEDWARD, Associate Member.*

(*Paper first received* 8*th April, and in final form* 1*st November*, 1937; *read before the* METER AND INSTRUMENT SECTION 1*st April*, 1938.)

SUMMARY

Asymmetry of E–I loops for nickel-iron cores under alternating magnetizing forces is shown to be due to residual polarization, the distribution of which throughout the cross-section of the stamping is different from the distribution of the flux due to the applied alternating magnetizing force. It is also shown that such polarization may, under certain conditions, be in different directions simultaneously in the inner and outer parts of the stamping. The polarization can be removed by applying a relatively large alternating magnetizing force and reducing it slowly to zero.

Curves are produced showing the amount of polarizing flux removed by different values of alternating magnetizing force, starting with a known value of residual flux. It is shown that in the case of mumetal the curves are different when the residual flux is caused by switching off alternating and direct current respectively. Other curves show the marked increase in polarizing flux produced by direct current when an alternating magnetizing force of suitable value is superimposed.

The reduction of apparent permeability due to residual polarization is also shown.

Strong polarization is found to occur, both in nickel-iron and in silicon-steel cores, under conditions in which capacitance loading of the secondary winding produces resonance with even harmonics, provided a small initial polarization is present. Initial polarization sufficient to allow this phenomenon to occur is found to be usually present, even when the normal loop is almost symmetrical.

The presence of even harmonics in the magnetizing current, as may occur, for instance, when the source of supply is a thermionic valve, is also found to cause polarization.

With certain values of capacitance loading of polarized specimens, sub-harmonics are produced.

The asymmetry of E–I loops for specimens with residual polarization is found to be less apparent as the frequency is raised above 50 cycles per sec.

It is pointed out that these phenomena should be taken into account in the design and operation of electromagnetic apparatus, but that cores of the more usual commercial forms will not exhibit the phenomena to the same extent as the plain ring stampings used in most of the tests described.

(1) INTRODUCTION

It is well known that residual magnetism is usually present in any magnetic core after the current in the magnetizing coil has been switched off. This is so whether the magnetizing current is direct or alternating. If the current is alternating, the amount of residual magnetism will depend upon the instant in the magnetization cycle at which the circuit is broken. If the alternating magnetizing current is reduced gradually to zero, there will usually be no residual magnetism, or polarization; and if there be any initial polarization, the application of a normal value of alternating magnetizing force, slowly reduced to zero, will usually remove such polarization.

In a recent paper by Dr. E. Hughes† some E–H and B–H loops were shown for nickel-iron alloys, and many of these loops were asymmetrical in form. This appeared to indicate polarization, but as it would normally be expected that residual polarization would have been removed by the alternating magnetizing force applied, and all tests failed to reveal any external cause, such as direct current in the windings, it appeared that there must be some phenomena in connection with the polarization of these particular alloys that are not normally encountered with the more familiar materials. The author set out to investigate these phenomena experimentally, and the results of this investigation are recorded in the present paper.

As the asymmetry is shown more clearly in loops formed by the primary current and secondary voltage than in B–H loops, all the loops given in this paper are obtained from the former quantities; and as in some of the experiments to be described there was a secondary current present it has been thought better to use the terms E and I rather than B and H. The symbol $(IT)_m$ will be used to indicate the peak value of the primary ampere-turns per cm., which is calculated in each case from the r.m.s. value of the sinusoidal primary current. The test frequency, except where otherwise stated, is 50 cycles per sec. In all the loops the current deflection is horizontal.

(2) PARTICULARS OF SPECIMENS

(A). Mumetal ring. This specimen was the one referred to as Specimen A in Dr. Hughes's paper, but was provided with extra windings. It consisted of 30 stampings, each $7\frac{1}{16}$ in. × $6\frac{1}{16}$ in. × 0·015 in.

Sectional area of iron = 1·452 cm.^{2}
Mean length of iron path = 52·4 cm.
Primary winding: 59 turns.
Secondary winding: 1 460 turns, centre-tapped.
Each winding covered the whole specimen.

(B). Mumetal ring. This specimen consisted of 6 ring stampings, each of the same dimensions as those used in Specimen A.

Sectional area of iron = 0·29 cm.^{2}
Primary winding: 59 turns.
Secondary winding: 7 300 turns, centre-tapped.
Each winding covered the whole specimen.

* Liverpool Corporation Electric Supply Department.

† *Journal I.E.E.*, 1936, vol. 79, p. 213.

(C). Mumetal ring consisting of spiral strip core made from 0·25 in. × 0·015 in. strip.

Sectional area of iron = 0·403 cm^2
Mean length of iron path = 51·8 cm.
Primary winding: 41 turns.
Secondary winding: 5 250 turns.

(D). Permalloy " C " ring consisting of spiral strip core made from 1 in. × 0·015 in. strip.

Sectional area of iron = 3·02 cm^2
Mean length of iron path = 20·2 cm.
Primary winding: 15 turns.
Secondary winding: 1 000 turns, centre-tapped.

(E). Permalloy " C " core consisting of 25 **E** stampings each 0·015 in. thick. The assembly of the stampings was such as to form a closed magnetic circuit, alternate stampings being reversed.

Sectional area of centre limb = 0·907 cm^2
Mean length of iron path = 7·8 cm.
Primary winding: 10 turns.
Secondary winding: 1 000 turns, centre-tapped.
The windings were on the centre limb.

(F) and (F1). E.S. stalloy rings. (The prefix " E.S." refers to the " extra special " grade of stalloy.) These were two identical specimens and each consisted of 6 stampings 15 cm. × 12 cm. × 0·014 in.

Sectional area of iron = 0·26 cm^2 (calculated from the weight of the complete assembly).
Mean length of iron path = 42·4 cm.
Primary winding: 100 turns.
Secondary winding: 6 580 turns.

(3) PRELIMINARY TESTS

The cathode-ray oscillograph used for showing the *E–I* loops was a Cossor Type–B gas-filled tube, and a gun voltage of 600 volts was employed. The circuit used is shown in Fig. 1. The broken-line portion of this Figure relates to some special tests referred to later. In the case of specimens C, F, and F1, in which the secondary winding was not centre-tapped, the earth connection was made to one end of the winding. A permanent magnet was used for centring the image.

As the supply voltage wave-form had an appreciable harmonic content, a large air-core inductance L was connected in series with the primary winding of the test specimen in order to ensure an approximate sinusoidal current.

As has been indicated, the loops referred to as *E–I* loops were formed by applying the secondary voltage E to the vertical deflecting plates, and passing the primary current I through the horizontal deflecting coils. The shape of some of the loops is somewhat similar to that of ordinary *B–H* loops turned through an angle of 90°, but it must be understood that this is merely a coincidence.

In illustrating the loops it has been thought preferable for the purpose of comparing the various specimens to use co-ordinates which are a function of the material of the specimen only, not of its dimensions. The ordinates are therefore plotted to a scale of

$$\frac{E}{\text{Secondary-coil turns} \times \text{Core cross-section}}$$

designated $E/(T_2A)$, and the abscissae to a scale of ampere-turns per cm., designated IT_1/cm. The symbol IT_1/cm., used for the loops, should not be confused with the symbol $(IT)_m$, used in the text and for some of the graphs, to indicate the alternating magnetizing force in terms of the peak value of ampere-turns per cm.

E–I loops for Specimen A when first tested are shown in Fig. 2. The primary current was raised slowly from zero by means of the potentiometer P, so that nothing was done in the preliminary tests to cause polarization; nevertheless, the loops show a very marked asymmetry. This appears to indicate strong polarization, although there is no evidence to show how this polarization has been caused. The maximum asymmetry was shown at $(IT)_m = 0{\cdot}124$ ampere-turn per cm. The current was then raised slowly to successively increasing values and each time reduced slowly to give $(IT)_m = 0{\cdot}124$. The asymmetry at this value became less and less marked as the maximum current was increased, until, when $(IT)_m$ had been raised to 6·75 ampere-turns per cm. and reduced to 0·124, the asymmetry had disappeared. The

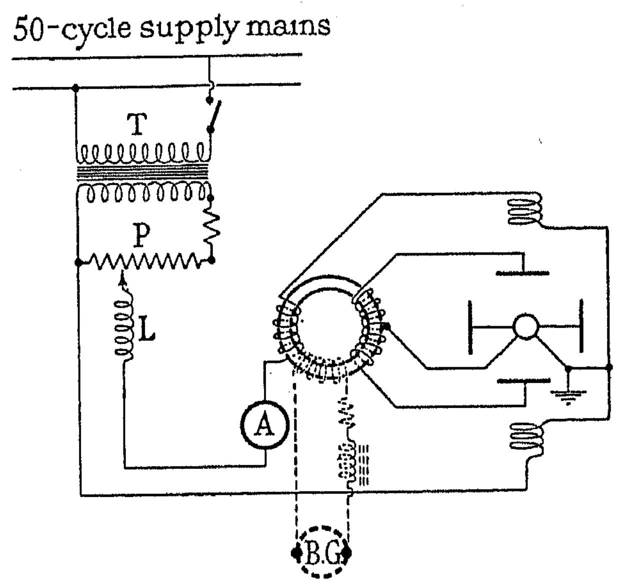


Fig. 1

loops shown in Fig. 3 were then obtained. These symmetrical loops indicate that the polarization had been removed.

It was then found that the asymmetry could again be produced by switching off the primary current suddenly, the amount of asymmetry depending principally upon the value at which the current was switched off. A " switching off " value of $(IT)_m = 0{\cdot}31$ was required to produce the asymmetry shown in Fig. 2, and no further increase in asymmetry was produced by increasing the " switching off " current.

As will be shown later, however, the polarizing flux could be increased and the a.c. magnetizing force required to remove the polarization very greatly increased by raising the value of the " switching off " current. Sometimes the asymmetry would appear reversed, indicating that the current was broken at a different point in the cycle, producing reversed polarization. The amount of asymmetry produced by switching off a current giving $(IT)_m = 0{\cdot}31$ or over was, however, nearly always the same. This indicated that, owing to a small amount of arcing at the switch contacts, the actual break tended to

occur at a similar point in the cycle every time, although it might sometimes occur in a positive and sometimes in a negative half-cycle.

The momentary application of direct current through a choke in series with a tertiary winding on the specimen was found to produce the same form of permanent asymmetry, the direction of asymmetry depending upon the direction of the momentary direct current.

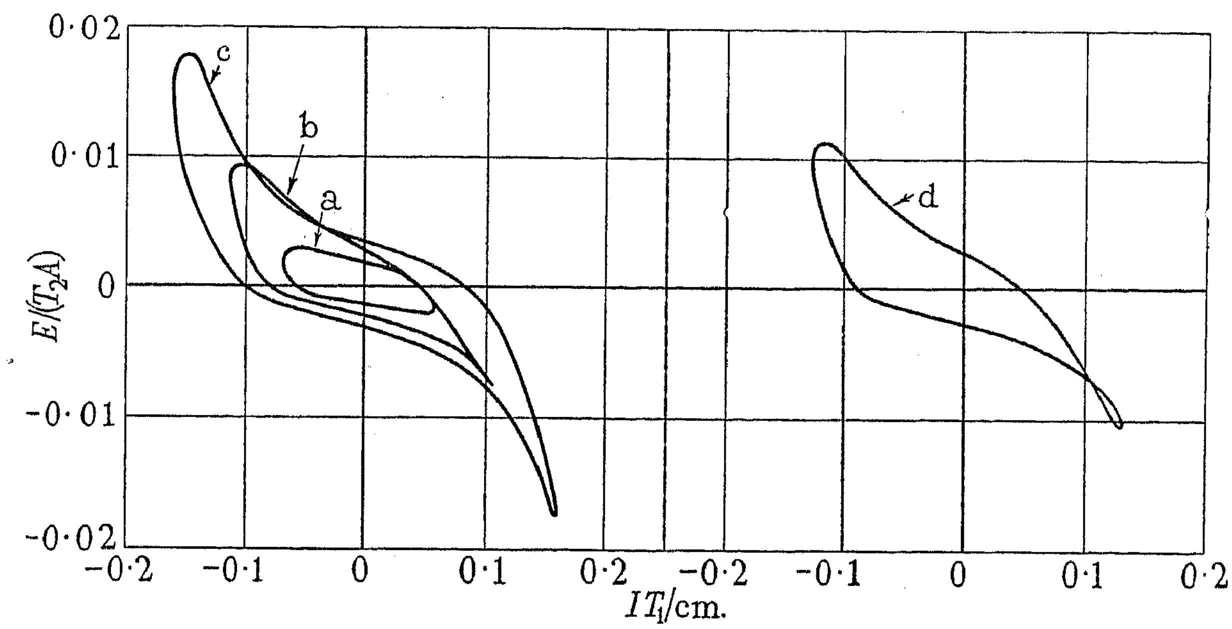


Fig. 2

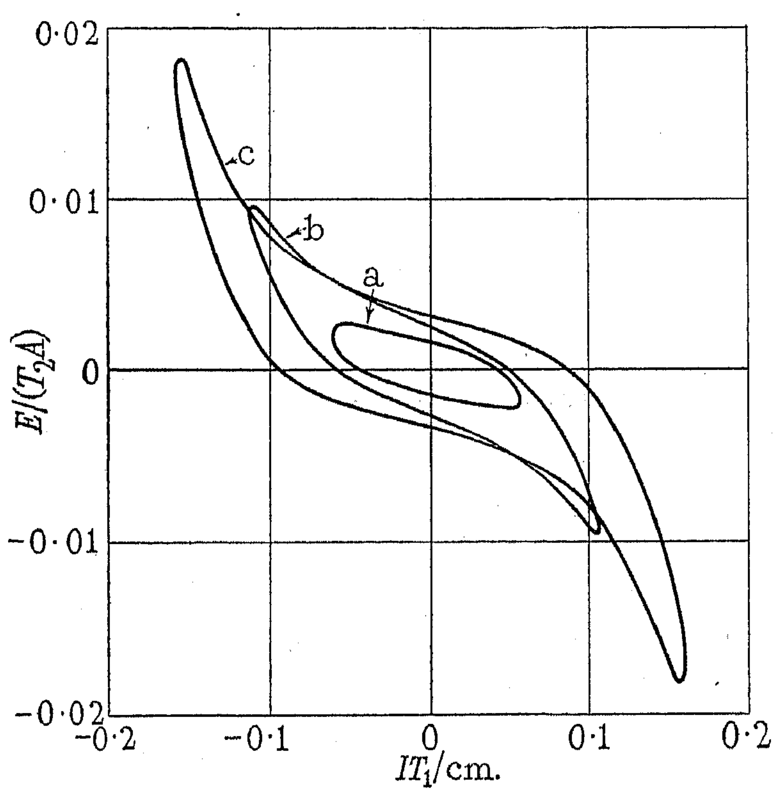


Fig. 3

firm this conclusion and to determine, if possible, the approximate amount of residual polarization produced under different conditions.

Specimen B was tested and gave the initial asymmetrical loops shown in Fig. 4. The symmetrical loops shown in Fig. 5 were obtained for this specimen after similar treatment to that accorded to Specimen A. In other tests also, the two specimens behaved in a similar manner.

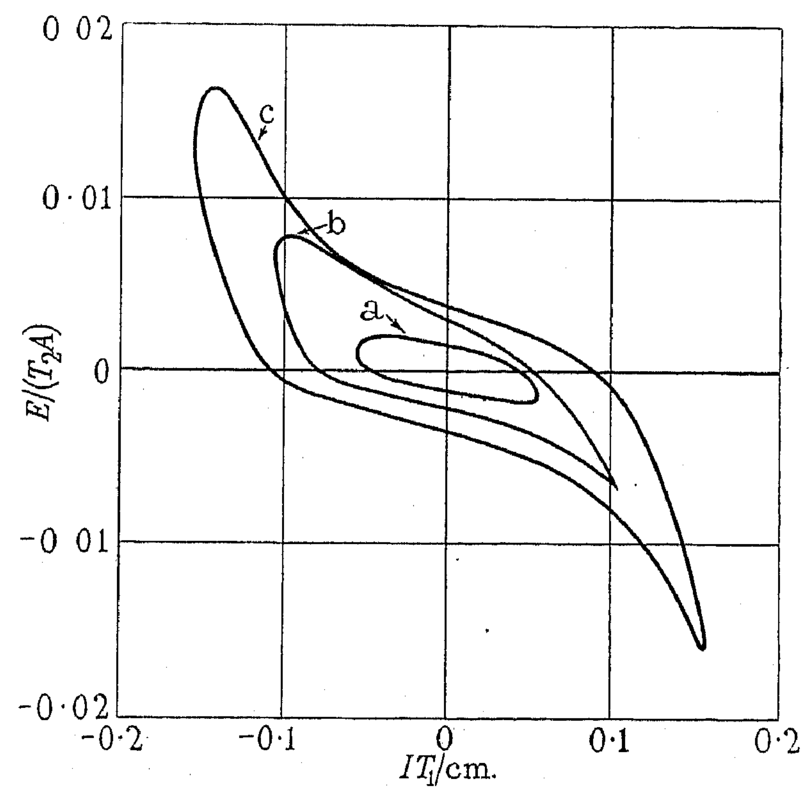


Fig. 4

(4) TESTS TO CONFIRM POLARIZATION AND TO DETERMINE AMOUNT OF POLARIZING FLUX

Although the foregoing tests appeared to show definitely that the asymmetry was due to residual polarization and that when the polarization was caused by switching off alternating current its value and direction depended upon the point in the cycle at which the current was broken, it was decided to make further tests to confirm this conclusion and to determine, if possible, the approximate amount of residual polarization produced under different conditions.

The primary windings of both specimens were then connected in series and the secondaries arranged so that either could be connected at will to the oscillograph. Both specimens were thus subject to the same conditions at any instant. After the specimens had been demagnetized, the current was raised slowly to successively larger values and switched off. It was then raised each

time to give $(IT)_m = 0 \cdot 124$. Under these conditions, the direction and the approximate amount of the asymmetry was always the same for both specimens. This indicated definitely that the direction of the asymmetry depended upon the point in the cycle at which the current was broken.

In the foregoing tests the primary current was broken by means of an ordinary hand-operated slow-break switch, and it has already been stated that under these conditions there appears to be a tendency to break at the same point in the positive or negative half-cycle, owing presumably to arcing at the contacts. In order to test the effect of breaking the current at different known points in the cycle, a trigger contact was arranged to be operated by a synchronous motor, and the instant of operation was adjustable so that any point in the cycle could be chosen at will. With a fixed magnetizing

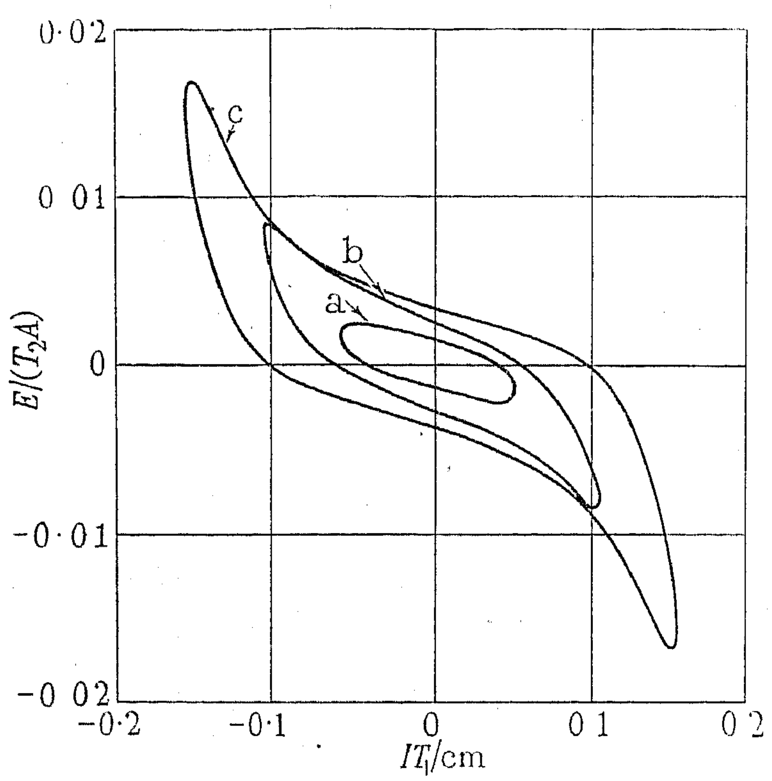


Fig. 5

current, the amount and direction of asymmetry were found to vary according to the point in the cycle at which the current was broken. It was noted that the asymmetry was in one direction when the current was broken at the positive current peak, and in the opposite direction when it was broken at the next zero point; by arranging the break to occur approximately midway between these two points a symmetrical loop was obtained.

This test might appear to indicate that the zero point of the flux wave occurred midway between a peak and a zero point of the current wave. Such an inference is, however, based on the assumption that the residual polarization is of the same order as the instantaneous value of flux density when the circuit is broken. It must be remembered that the effect of hysteresis may considerably modify the relation between these two quantities.

A tertiary winding on Specimen A was then connected in series with a choke and resistance to a ballistic galvanometer, as shown by the broken line in Fig. 1. The specimen was then demagnetized, and a symmetrical loop was obtained at $(IT)_m = 0 \cdot 124$. The current was then raised slowly to give $(IT)_m = 0 \cdot 31$. When the current was switched off the ballistic galvanometer gave a deflection, and the loop obtained when the current was again raised to give $(IT)_m = 0 \cdot 124$ was asymmetrical. While the current was being raised to a high value to remove the polarization the galvanometer gave a deflection in the opposite direction. When the current was slowly decreased to give $(IT)_m = 0 \cdot 124$ a symmetrical loop was again obtained.

From the ballistic constant of the galvanometer—already determined—the change in the mean flux could be ascertained. Thus, if an a.c. magnetizing force was applied to a polarized specimen, the galvanometer would indicate the amount of polarizing flux removed. In tests made to determine the amount of polarizing flux removed by alternating current it was found preferable to raise the current quickly by means of a potentiometer, rather than to switch it on suddenly, particularly when working on the steep part of the magnetization curve. It is well known that when an alternating voltage is switched on suddenly to an inductive circuit, a d.c. transient occurs. On the steep part of the magnetization curve this may be sufficient to affect the polarization and thus give spurious readings. When any value of alternating current was applied to a non-polarized specimen—by raising the current quickly by means of the potentiometer—the galvanometer gave no deflection. It became clear during these tests, however, that it is not always easy to ensure that a mumetal specimen is completely demagnetized by the application of alternating current.

It was found generally that if the primary current was broken at any given value, the residual polarization as indicated by the ballistic-galvanometer deflection on breaking could be removed by applying the same current again. Thus if the specimen was demagnetized and $(IT)_m = 0 \cdot 124$ applied, then if the current was broken and remade the loop would still be symmetrical. The ballistic-galvanometer deflections on breaking and remaking were equal and opposite.

When the current was broken at $(IT)_m = 0 \cdot 31$ the flux density of polarization had a mean value of 4 140 gauss; then when alternating current was applied to give $(IT)_m = 0 \cdot 124$ the polarizing flux removed was equivalent to an average density of 2 624 gauss. This left a polarizing flux density of 1 516 gauss, which was retained even while the alternating magnetizing force of $(IT)_m = 0 \cdot 124$ was present, and gave rise to an asymmetrical loop, as shown at *d* in Fig. 2. It should be noted that the a.c. magnetization for $(IT)_m = 0 \cdot 124$ was over 3 000 gauss (maximum).

As has been previously indicated, all the values of $(IT)_m$ are the maximum values of ampere-turns per cm. calculated from the measured r.m.s. values of sinusoidal current. In no case do they refer to instantaneous values of breaking or making of the current.

(5) CAUSE OF RESIDUAL POLARIZATION BEING RETAINED UNDER THE INFLUENCE OF ALTERNATING MAGNETIZING FORCES

As was indicated in the paper by Dr. Hughes, the a.c. magnetization at the centre of the stamping, at low and

medium values of magnetizing force, is probably only a small fraction of that at the surface. It would therefore seem reasonable to suppose that if the residual polarization was initially uniform—and this would seem likely to be approximately so when the current was broken at $(IT)_m = 0 \cdot 31$—or if the polarization at the centre was fairly high, then the lower value of a.c. magnetizing force, namely $(IT)_m = 0 \cdot 124$, would only remove the outer polarization, or would cause the polarization to become non-uniform, having a decreasing value from the centre to the surface.

(6) TESTS TO CONFIRM THEORY

The following tests were made to confirm this theory:—

With Specimen A in an initially non-polarized condition, the fact was established that when a d.c. magnetizing force of suitable value was applied and switched off, exactly balanced by a uniform polarizing force of opposite sign. It should be mentioned that the direct current was applied to a tertiary winding through a large choke, and care was taken to ensure that the a.c. component in this circuit was negligible and did not affect the form of the loop.

Loop *b* in Fig. 6 was produced by a d.c. magnetizing force of $0 \cdot 0028$ ampere-turn per cm. superimposed on an a.c. magnetizing force of $(IT)_m = 0 \cdot 124$. No variation of direct current would produce exactly the same form of loop as *d* in Fig. 2. If we assume, therefore, that with direct current present in Case (*b*) the polarization is approximately uniform, it is apparently non-uniform when the direct current is absent.

Curves were plotted showing (i) the polarization produced by switching off alternating current at different values of $(IT)_m$, and (ii) the polarization removed by

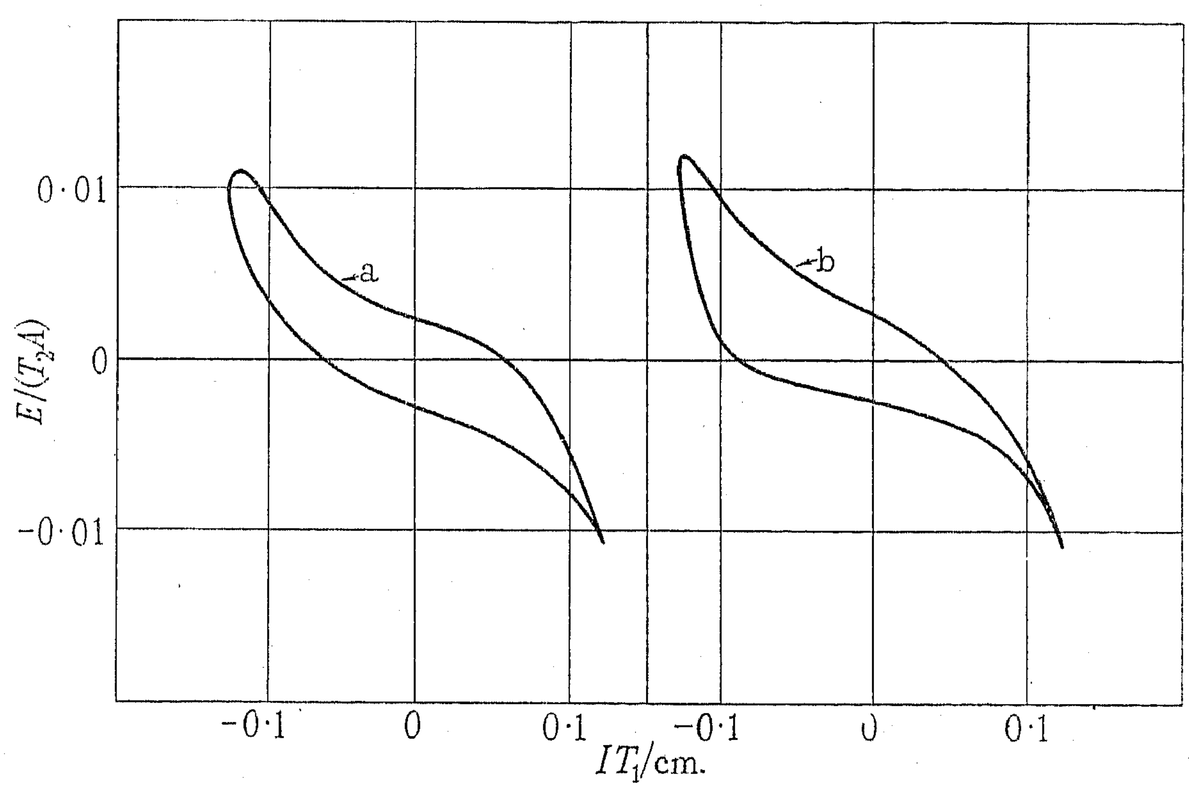


Fig. 6

then upon applying alternating current the asymmetry was of exactly the same form as that produced by switching off alternating current. If the polarization remains uniform while the specimen is under the influence of a.c. magnetization, the following effects should be possible: (*a*) The asymmetry should be obliterated if direct current of suitable value and sign is continuously applied. (*b*) If direct current of suitable value is continuously superimposed on alternating current with an initially non-polarized specimen, the asymmetry produced should be exactly the same as that produced by a polarized specimen with no direct current present.

Neither (*a*) nor (*b*) was found to be possible. Thus the loop shown at *a* in Fig. 6 illustrates the attempt to obliterate the asymmetry by the application of an opposing d.c. magnetizing force. The loop as shown is the nearest approach to symmetry that could be produced in this way. Further increase of direct current reversed the asymmetry. The explanation would appear to be that the initial polarization, being non-uniform, cannot be applying alternating current at different values of $(IT)_m$. Fig. 7 shows the residual polarization for Specimen A (mumetal) produced by switching off alternating current, while Fig. 8 shows the corresponding curve for Specimen F (E.S. stalloy). In these two curves the highest value of three readings was taken for each test.

In Fig. 9 two curves are shown for Specimen A, illustrating the removal of polarization, the initial value being 4 460 gauss—produced by switching off alternating current at $(IT)_m = 4 \cdot 0$. Curve *a* shows the polarization remaining while the alternating current was present, whereas *b* shows the polarization remaining after the alternating current had been reduced slowly to zero each time. The significance of these two curves is that although the mean value of polarizing flux may be considerably reduced while the alternating current is present, it returns to a large value when the alternating current is reduced slowly to zero. This effect is seen to occur over a large portion of the curves. Fig. 10 shows the same

effect when the initial polarization was 4 140 gauss, produced by switching off alternating current at $(IT)_m = 0 \cdot 31$. It is evident that a slow reduction of alternating current to zero cannot of itself cause polarization—and in fact

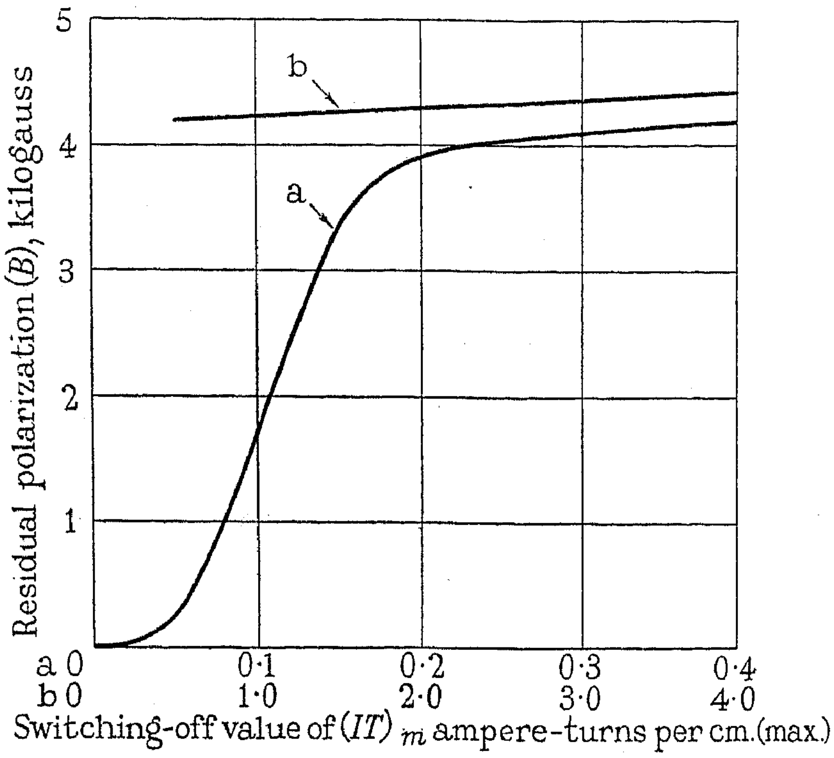


Fig. 7.—Mumetal: residual polarization caused by switching off alternating current.

does not do so when an initially non-polarized specimen is treated in this way—so that the return of a large polarizing flux under the conditions stated must be due to some property of the specimen.

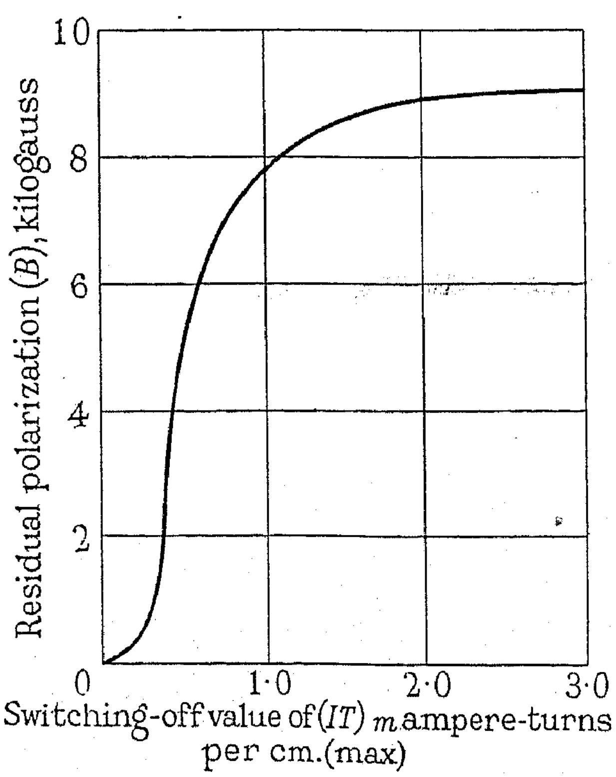


Fig. 8.—E.S. stalloy: residual polarization caused by switching off alternating current.

It should be noted here that the a.c. "switching off" values were such as would be expected to produce fairly uniform initial polarization, particularly in the case of Fig. 9, where the "switching off" value was very high.

Under these conditions one would expect the curves to be similar whether the polarization was produced by switching off either alternating current or direct current, and this was found to be the case. If, on the other hand, a

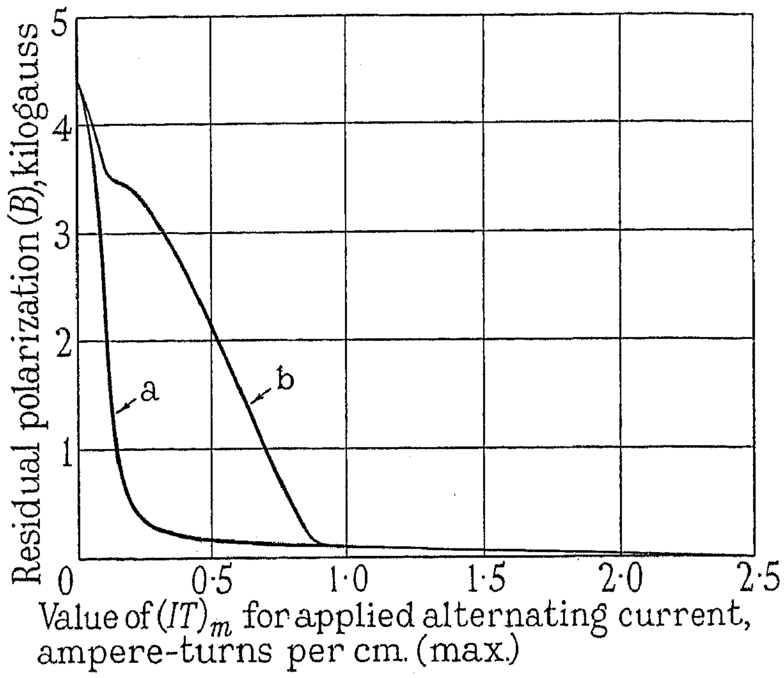


Fig. 9.—Mumetal: removal of residual polarization.

comparatively low value of alternating current was switched off, the initial polarization would presumably be non-uniform, having an increasing value from the centre to the surface of the stamping, and the value obtained by the ballistic galvanometer would be an average value. If the same value of initial polarization was subsequently produced by direct current, it would be uniform and the demagnetization curves for the two cases would not be similar, a greater value of alternating current being required to remove completely the polariza-

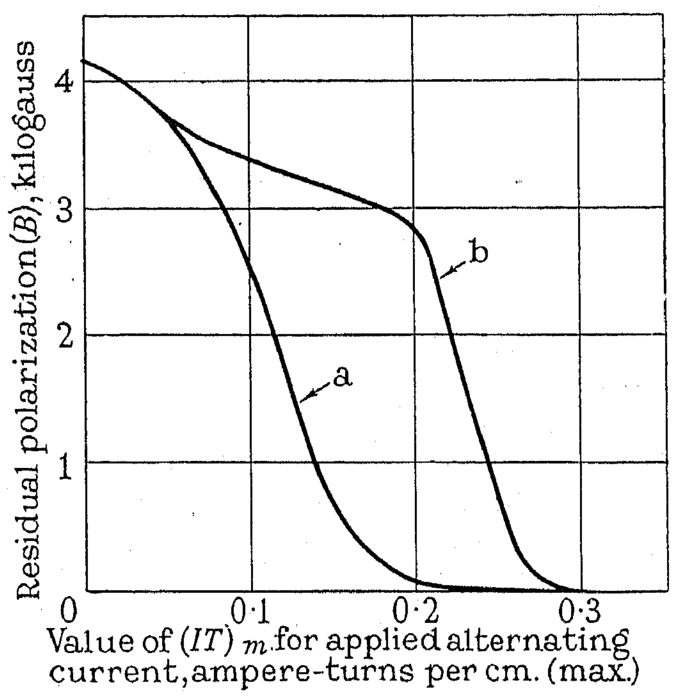


Fig. 10.—Mumetal: removal of residual polarization.

tion produced by direct current. The curves shown in Fig. 11 confirm this reasoning. The initial polarization was 1 945 gauss, and in the case of Curve *a* it was produced by switching off alternating current at $(IT)_m = 0 \cdot 13$,

whereas in the case of Curves *b* and *c* it was produced by switching off direct current having a value giving 0·044 ampere-turn per cm. The difference in the demagnetization curves for polarization caused by switching off alternating current and direct current respectively is thus very marked for this value of polarization. Curve *a* shows the mean polarization when the alternating current was present; the curve of polarization remaining when the alternating current was slowly reduced to zero each time was substantially the same. The effect noted in the case of Figs. 9 and 10 was therefore absent with this low " switching off " value of alternating current. The effect was, however, found to be present when the same polarization was produced by direct current. Curve *b* shows the mean polarization when the alternating current was present, while Curve *c* shows the polarization remaining when the alternating current was slowly reduced to zero each time. It should be mentioned that it was found impossible to obtain very

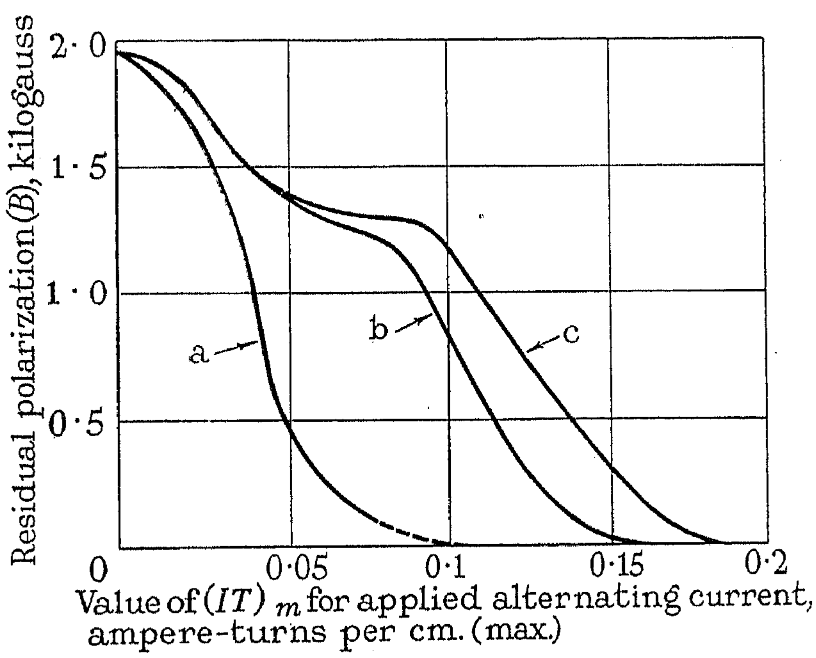


Fig. 11.—Mumetal: removal of residual polarization.

accurate readings for the small broken-line portion at the bottom of Curve *a*, Fig. 11. In this region the polarization showed a tendency to reverse.

In producing the curves showing the mean polarization when the alternating current was present, the amount of flux removed was determined from the galvanometer swing upon applying each value of alternating current and the figure obtained was deducted from the value of initial polarization, already determined as previously described. The specimen was fully demagnetized after each reading and remagnetized to the original value of initial polarization.

In producing the curves showing the polarization remaining when the alternating current was reduced slowly to zero each time, the residual polarization was completely removed each time by applying a sufficiently large magnetizing force, and the value removed was determined directly from the galvanometer swing.

Figs. 12 and 13 show demagnetization curves for Specimen F (E.S. stalloy). In Fig. 12 the initial polarization was 7 280 gauss, produced by switching off alternating current at $(IT)_m = 0\cdot8$; while in Fig. 13 the initial polarization was 1 950 gauss, produced by switching off alternating current at $(IT)_m = 0\cdot36$. The curves were substantially the same when the same initial polarization was produced by switching off direct current,

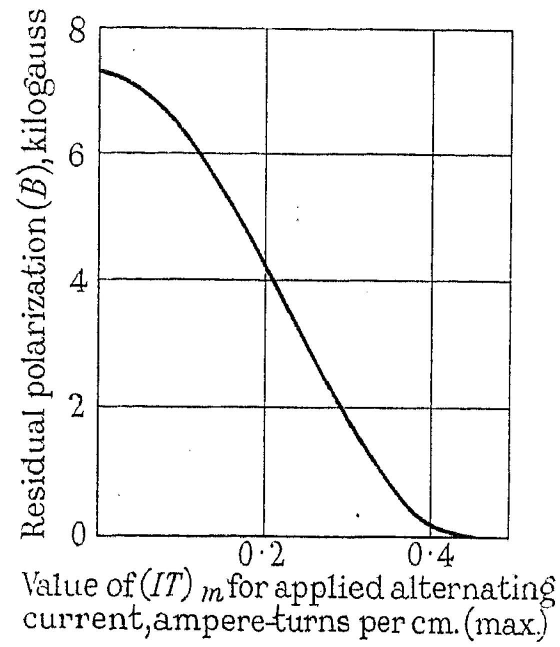


Fig. 12.—E.S. stalloy: removal of residual polarization.

and no appreciable difference was found between the values of the residual polarization when the alternating current was present and the values when the alternating current was reduced to zero each time. In other words, mumetal and stalloy appear to behave quite differently in these respects.

Referring again to the mumetal curves of Figs. 9 and 10, the initial polarization in both cases would presumably be fairly uniform, and the low and medium values of a.c. " demagnetizing " force would not appre-

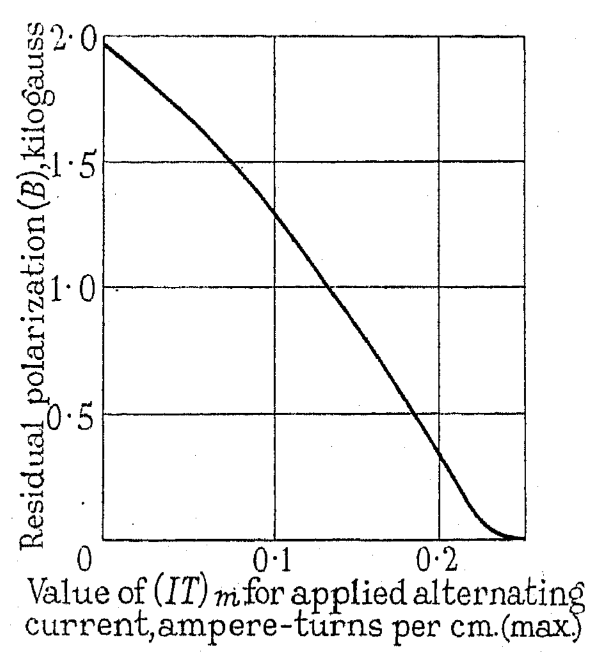


Fig. 13.—E.S. stalloy: removal of residual polarization.

ciably affect the polarization at the centre. When the a.c. " demagnetizing " force is reduced to zero, the strong polarization at the centre appears to affect the outer portion of the stamping again, so that a considerable proportion of the initial polarization returns. It is not suggested that this is the only possible explanation of this

phenomenon, but it appears to be a likely one in view of the fact that the phenomenon is not exhibited by stalloy —or at any rate only to a very small extent. Also, Curve *a* in Fig. 11 shows that it is not exhibited by mumetal when the initial polarization does not affect the inner part of the stamping to any appreciable degree.

(7) POLARIZATION IN OPPOSITE DIRECTIONS SIMULTANEOUSLY IN DIFFERENT PARTS OF THE STAMPING

Specimen (A) was polarized by switching off alternating current at $(IT)_m = 4 \cdot 0$, the intention being to produce strong polarization in the inner portion of the stamping. Curve *a* in Fig. 14 indicates the asymmetry then shown at $(IT)_m = 0 \cdot 124$. The current was then raised from the value giving $(IT)_m = 0 \cdot 124$ to a value giving $(IT)_m = 0 \cdot 31$, and repeated switching-off was tried at this value until a reversed asymmetry was indicated at $(IT)_m = 0 \cdot 124$, as shown in Curve *b* of Fig. 14. As the polarization giving rise to this reversed asymmetry was produced by switching off at this considerably lower value of $(IT)_m$, it is reasonable to suppose that the original polarization at the centre of the stamping was not reversed. That this was the case was indicated by the fact that when $(IT)_m$ was again slowly raised to $0 \cdot 31$ to remove the outer polarization and was then reduced slowly to $0 \cdot 124$ once more, the asymmetry again assumed the original direction, though it was slightly less marked. This is shown in Curve *c* of Fig. 14. Fig. 15 shows graphically the progress of the above experiment as indicated by ballistic-galvanometer tests.

It appears from these tests that polarization can be present in opposite directions simultaneously in different parts of the stamping. In the test just described, it was found that when the current was raised slowly step by step to remove the outer polarization and reduced to give $(IT)_m = 0 \cdot 124$ after each increase, the asymmetry due to the outer polarization was reduced step by step until a symmetrical, but unstable, loop appeared. Further increases reversed the asymmetry until Curve *c* of Fig. 14 was shown.

The unstable symmetrical form no doubt appears when equal and opposite polarizing fluxes are present in different parts of the stamping.

The symmetrical form of loop produced by reducing a relatively large current slowly to zero, as previously described, remains perfectly stable even if the specimen is left for some days and then retested.

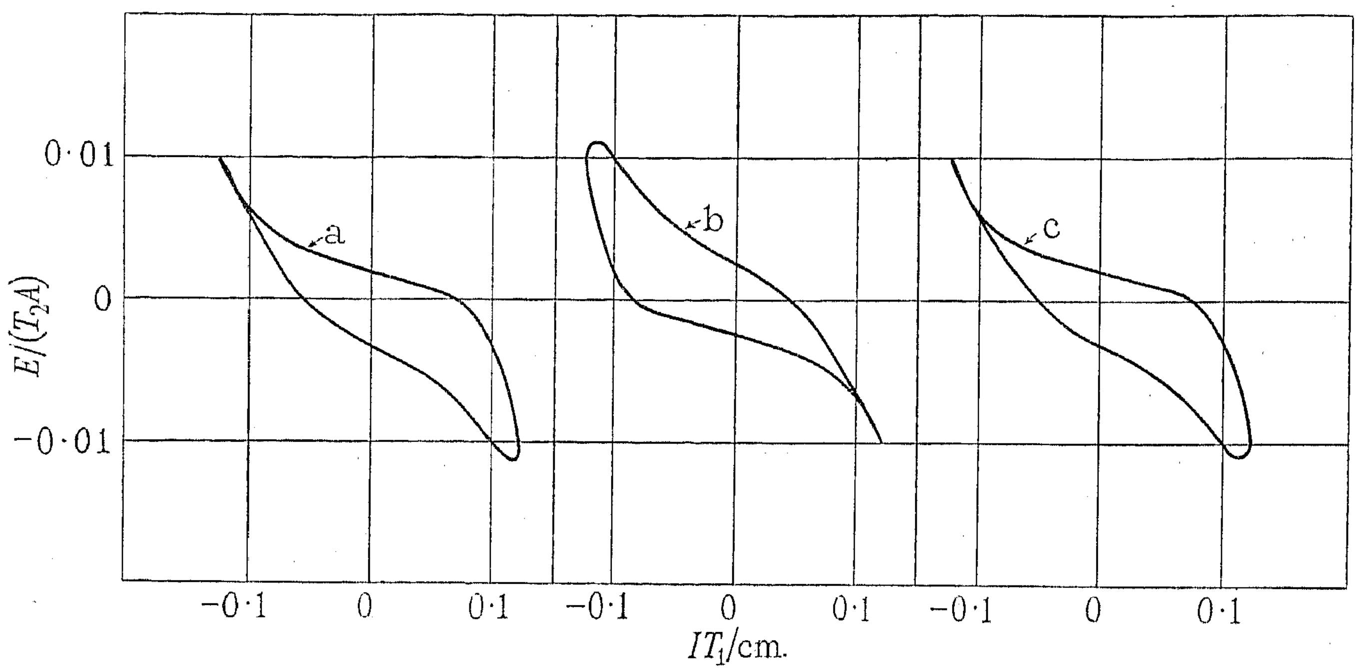


Fig. 14

Simultaneous polarization in opposite directions in different parts of the stamping can sometimes be produced by switching off alternating current at a fairly high value from an initially non-polarized specimen. If the current is then slowly raised from zero, the asymmetry will sometimes appear in one direction at a very low value of $(IT)_m$ and will reverse when the current is increased.

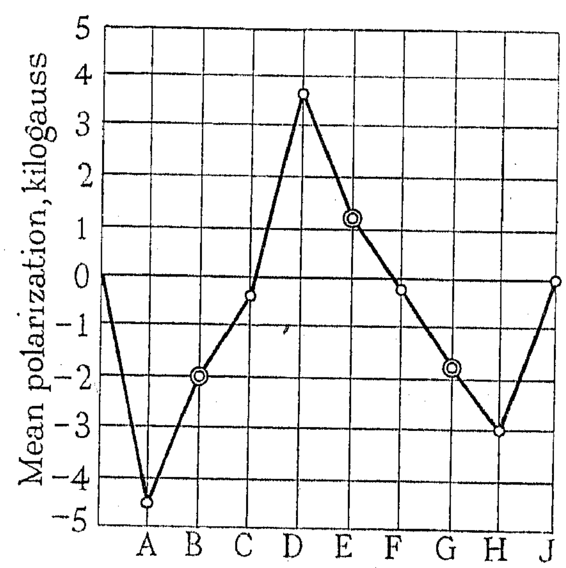


Fig. 15

A. Break at $(IT)_m = 4 \cdot 0$.
B. Make at $(IT)_m = 0 \cdot 124$ (see Curve *a*, Fig. 14).
C. Raise to $(IT)_m = 0 \cdot 31$.
D. Break at $(IT)_m = 0 \cdot 31$.
E. Make at $(IT)_m = 0 \cdot 124$ (see Curve *b*, Fig. 14).
F. Raise to $(IT)_m = 0 \cdot 31$.
G. Reduce to $(IT)_m = 0 \cdot 124$ (see Curve *c*, Fig. 14).
H. Reduce to $(IT)_m = 0 \cdot$
J. Make at $(IT)_m = 4 \cdot 0$.

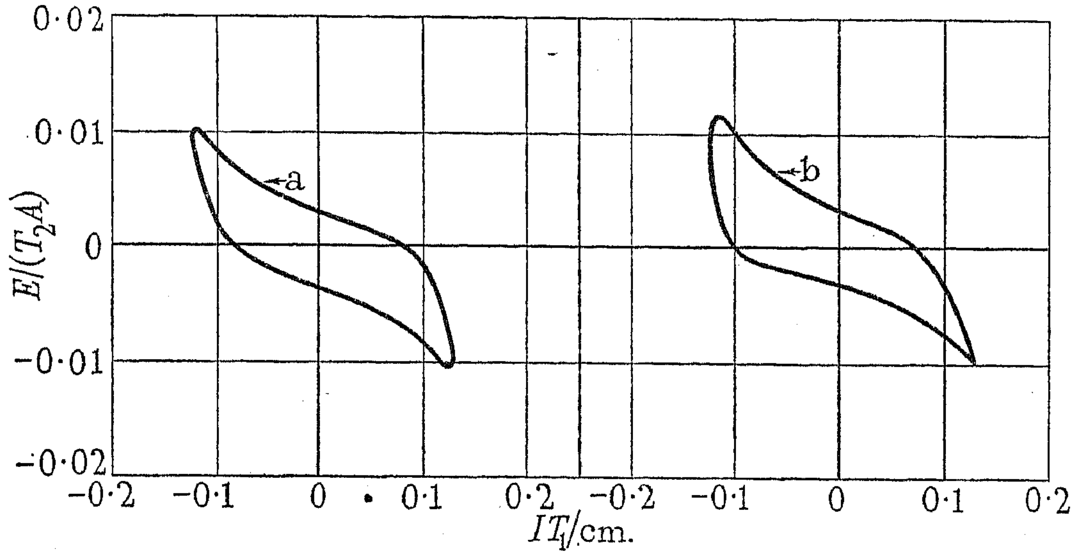


Fig. 16

This would appear to be explained by the fact that, as pointed out in Dr. Hughes's paper, a large phase-difference may exist between the a.c. fluxes at the inner and outer parts of the stamping, so that at particular instants in the cycle these fluxes will be in opposite directions. If the circuit is broken at such an instant, therefore, the residual polarization will be in opposite directions at the inner and outer parts of the stamping. When this reversal of asymmetry has been observed upon increasing the current, if the current is again reduced to zero, upon again raising it the asymmetry appears in the last observed direction at all values of $(IT)_m$, thus indicating that the asymmetry observed in the first instance at a low value of $(IT)_m$ was due to polarization of the outer part of the stamping, and that this polarization was removed upon increasing the current.

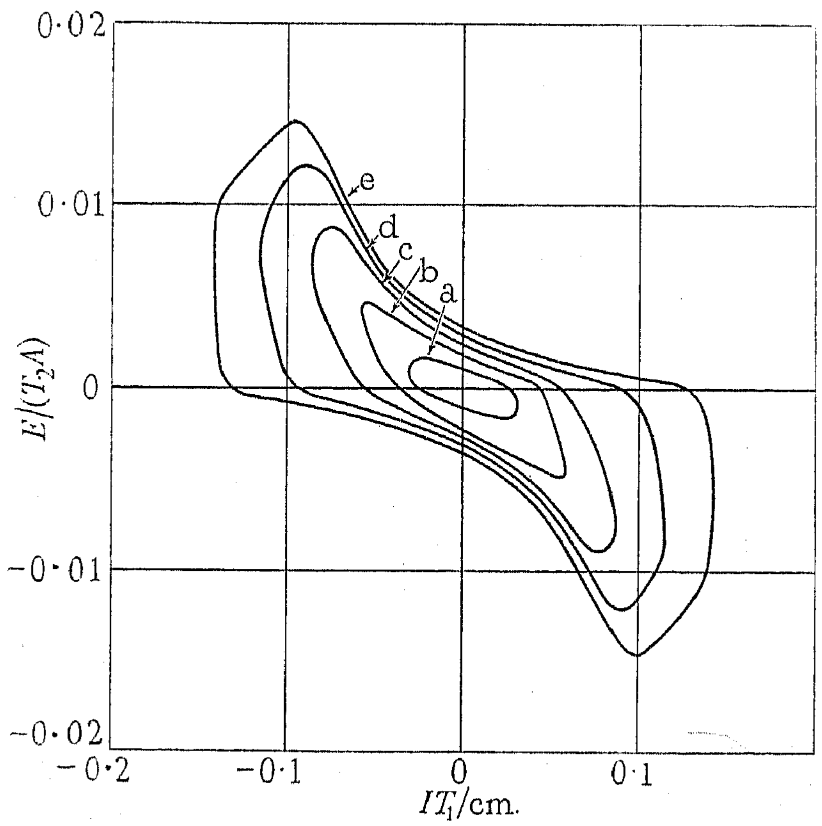


Fig. 17

These latter observations may appear to conflict with some of the explanations offered with regard to other phenomena, where it has been suggested that at high values of $(IT)_m$ the a.c. magnetization is fairly uniform, but it should be pointed out that in the case just referred to the polarization was apparently in the same direction throughout the greater portion of the section of the stamping.

(8) TESTS OF SPECIMENS OTHER THAN MUMETAL RING STAMPINGS

The maximum asymmetry that could be produced with other specimens is shown in the following loops: *b*, Fig. 16, Specimen C (mumetal spiral core); *b*, Fig. 17, Specimen D (permalloy " C " spiral core).

Specimen E (built up from permalloy " C " E-shaped stampings, assembled to form a closed magnetic circuit by reversing alternate stampings) showed no asymmetry unless polarization was maintained by some means such as a d.c. magnetizing force. The loops obtained for this specimen are shown in Fig. 18.

Specimens F and F1 (E.S. stalloy rings) showed no asymmetry except with artificially-maintained polarization, but at low values of $(IT)_m$ any large initial polarization was partly retained, as shown by a decrease in the secondary voltage. This is illustrated in Fig. 19, which shows:—

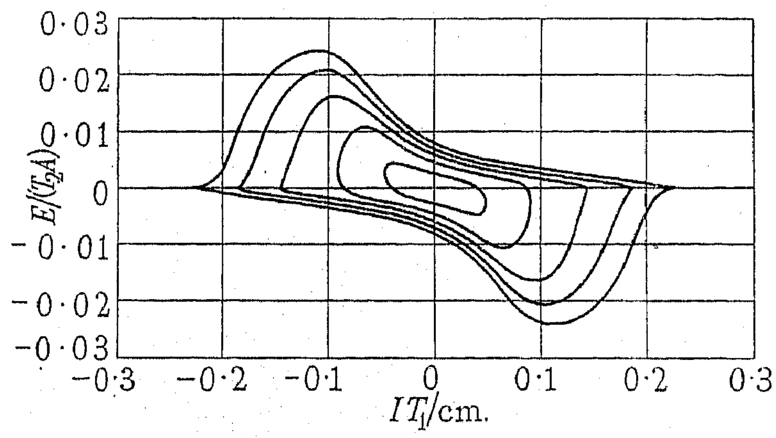


Fig. 18

Loop *a*, non-polarized stalloy at $(IT)_m = 0\cdot25$.

Loop *b*, the same after raising $(IT)_m$ to $1\cdot0$ and then polarizing by suddenly reducing $(IT)_m$ to $0\cdot25$.

Loop *c*, the effect on *b* of slowly increasing $(IT)_m$ to $0\cdot36$.

When the current was then reduced to give $(IT)_m = 0{\cdot}25$, Loop *a* was again obtained, thus indicating the ease with which the temporary polarization was removed.

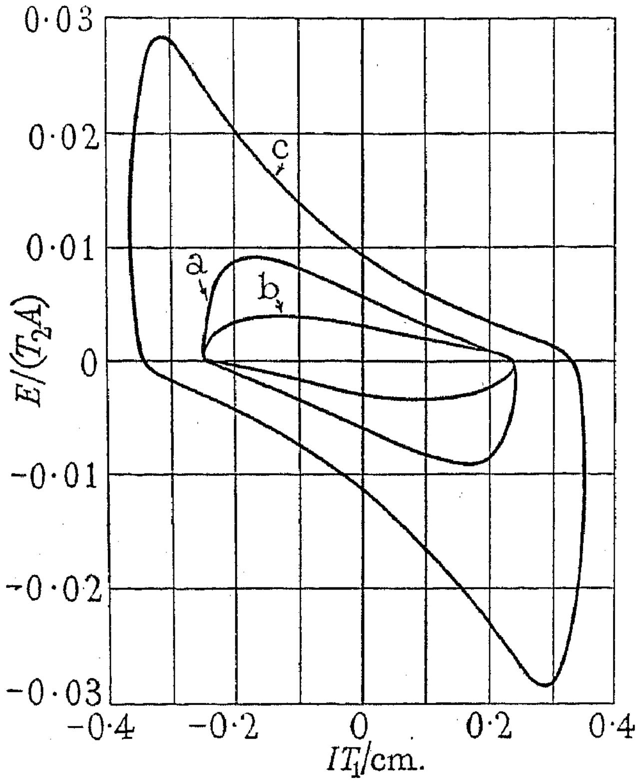


Fig. 19

(9) EFFECT OF FREQUENCY

Tests were made with a polarized specimen to show the effect on the *E–I* loop of raising the frequency. Fig. 20 shows loops for the same primary current applied to Specimen B; Loop *a* was obtained at 50 cycles per sec., Loop *b* at 150 cycles per sec., and Loop *c* at 550 cycles per sec. It will be noticed that the asymmetry becomes less marked as the frequency is raised. The rounding of the tips of the loop which is also found with non-polarized specimens may account to some extent for the lessened asymmetry, but the smaller depth of penetration of the flux at higher frequencies may also have an appreciable effect, owing to the polarization near the surface being comparatively small.

Tests showed that the higher frequencies had no effect in either reducing or increasing the actual residual polarization.

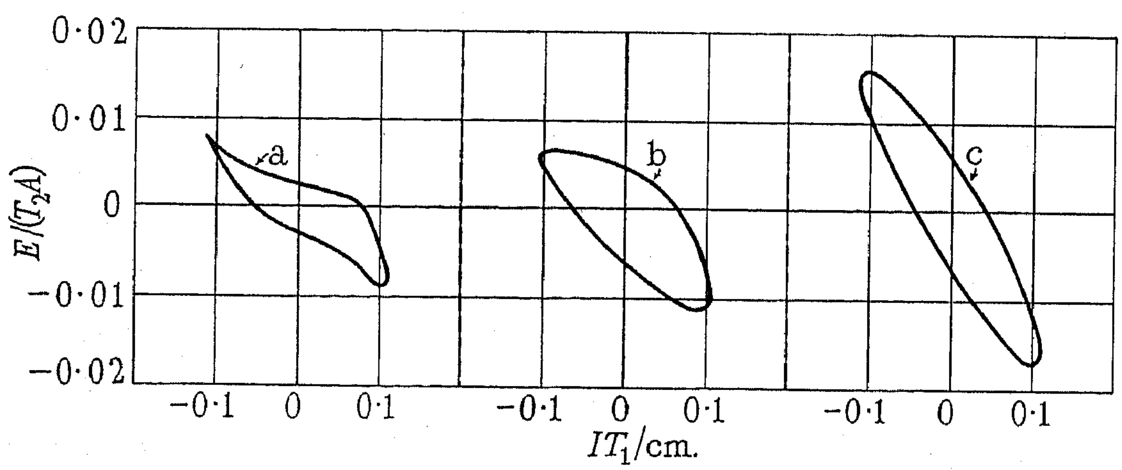


Fig. 20

(10) EFFECT OF RESIDUAL POLARIZATION ON APPARENT PERMEABILITY

The apparent-permeability curves at a frequency of 50 cycles per sec. were plotted for Specimen A, first with

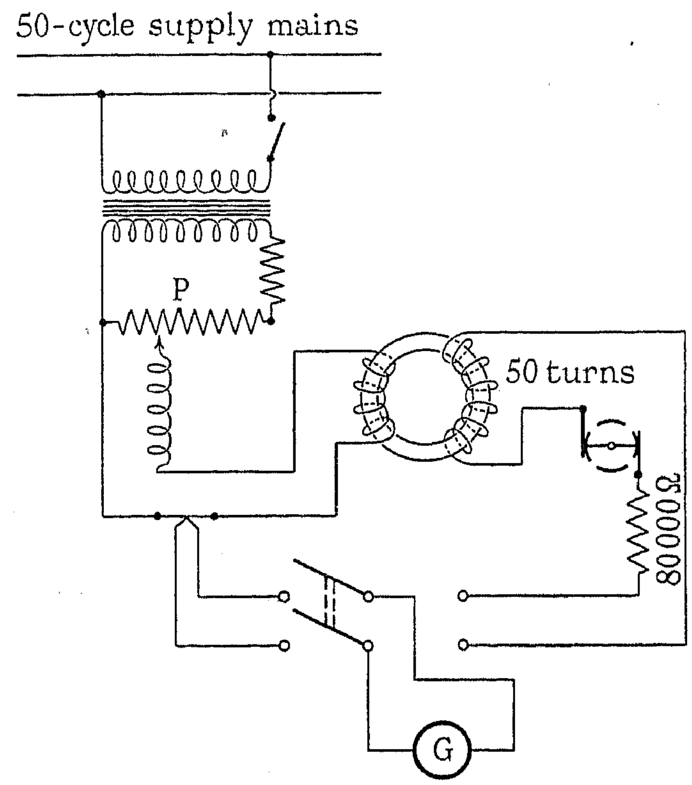


Fig. 21

the specimen non-polarized and showing a symmetrical loop, and then with polarization of 4 140 gauss produced by switching off the primary alternating current at $(IT)_m = 0{\cdot}31$. The curves obtained are shown in Fig. 22. It will be seen from the circuit diagram (Fig. 21) that a thermocouple was used for r.m.s. current measurement, while a synchronous rectifier was used for measuring mean volts. H_{max} values were taken as equal to $(IT)_m \times 1{\cdot}257$, and B_{max} values were calculated from the mean volts in the familiar manner. Then,

$$\text{Apparent permeability } (\mu) = \frac{B_{max}}{H_{max}}$$

The curves show the difference in apparent permeability due to residual polarization. It should be noted that

in this particular case the polarization was gradually removed during the progress of the test.

(11) APPARENT SELF-POLARIZATION BY CAPACITANCE LOADING OF SECONDARY WINDING

A comparison of Figs. 2 and 4 for Specimens A and B respectively—which are both of the same material but of different core sections—will show that the larger specimen (A) has a cross-over at the lower tip of Loop *d* that is not present in any of the loops for Specimen B. The phase angle between current and voltage is therefore slightly different for the two specimens, and it was found that a capacitance of $0{\cdot}004\ \mu F$ connected across the secondary winding of the smaller specimen (B) would produce a similar cross-over at the tip of the loop.

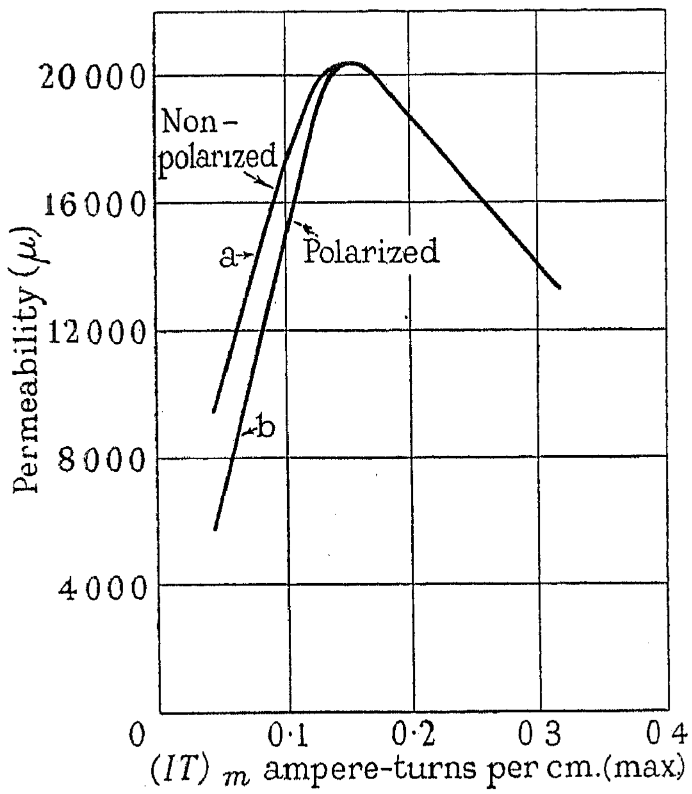


Fig. 22

This led to further experiments with capacitance loading, and it was found that, starting with an apparently non-polarized specimen, certain values of capacitance loading and primary current seemed to cause self-polarization of the specimen. This was found to apply not only to the nickel-iron alloys but also to the silicon-steel (stalloy) specimens. As two similar stalloy specimens were used together in some of the investigations of this effect, the descriptions of relevant tests will be mostly confined to these specimens.

Fig. 23 shows: Loop *a*, a normal loop for Specimen F with $(IT)_m = 0{\cdot}55$. Loop *b*, the effect on Loop *a* of connecting a capacitance of $0{\cdot}1\ \mu F$ across the secondary.

The change from *a* to *b* did not take place instantly. During the initial quick change of form the loop remained symmetrical, but gradually assumed the asymmetrical form shown in about 2 sec. Upon removing the capacitance, the loop returned to the form shown at *a*. In this connection it may be mentioned that when a mumetal specimen was used some polarization remained after disconnection of the capacitance, as shown by a fairly marked asymmetry.

The above results were the same whether the capacitance was connected before or after raising $(IT)_m$ to $0{\cdot}55$. The asymmetry was also the same after $(IT)_m$ had been raised to any higher value at which the loop became symmetrical and reduced again to $0{\cdot}55$.

A ballistic galvanometer, connected as shown by the broken line in Fig. 1 while this effect was being observed, recorded a deflection while the loop was changing from the symmetrical to the asymmetrical form. A reversed deflection was shown upon either removing the capacitance or increasing $(IT)_m$.

(12) CAUSE OF APPARENT SELF-POLARIZATION BY CAPACITANCE LOADING

The cause of this "self-polarization" would appear to be as follows:—

(*a*) In the case of a polarized specimen supplied with sine-wave current, the induced voltage wave-form is not symmetrical about the zero axis and therefore contains even harmonics.

(*b*) A specimen which appears to be non-polarized may actually be very slightly polarized in one direction or the other. In such a case, even harmonics will be present in the voltage wave-form, although their amplitude may

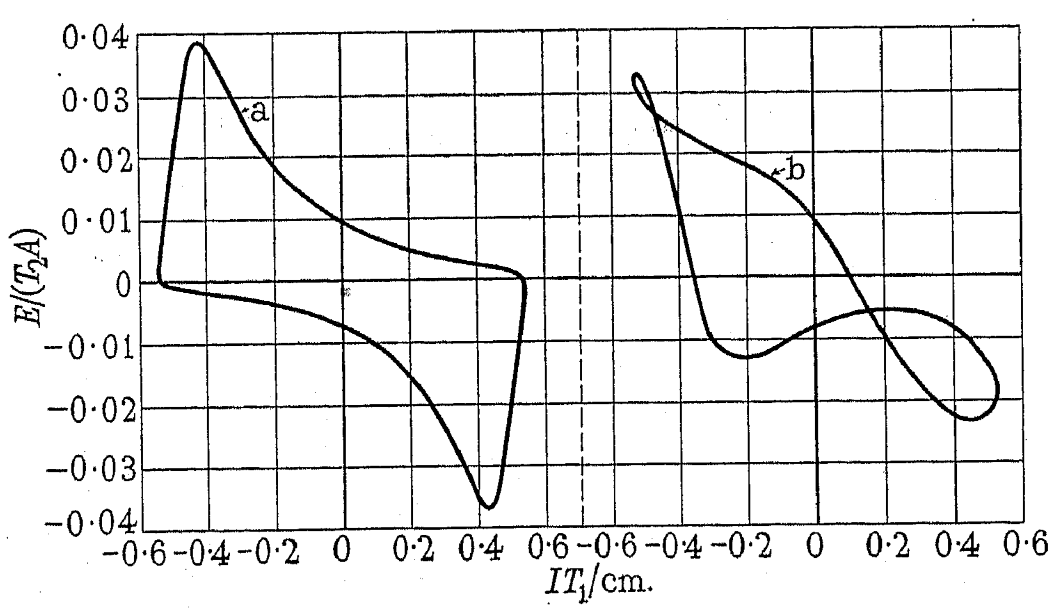


Fig. 23

be so small as not to be perceptible upon ordinary inspection of the voltage wave, or the E–I loop.

(*c*) A condition of resonance with an even harmonic, say the second, may be produced by a certain combination of flux density and secondary capacitance loading.

(*d*) The existence of conditions (*b*) and (*c*) will cause a second-harmonic current to flow in the secondary winding. The effect of resonance will be to cause this second-harmonic current to assume a fairly large value, the second-harmonic voltage increasing with the current.

(*e*) A second-harmonic current in such phase relationship to the fundamental as to give a wave-form that has unequal positive and negative peaks will polarize the core, so that the initial slight polarization will increase with the increasing current, thus further increasing the amplitude of the second harmonic—and other even harmonics—the effect being cumulative until strong polarization ensues.

With regard to (*e*), it seems clear that if the positive and negative peaks of the current wave, and therefore of the flux wave, are unequal, polarization will ensue owing to hysteresis.

(13) TESTS TO CONFIRM THEORY

Experiments were made in order to test the above theory. Taking each statement or assumption in order, the following observations may be made.

(*a*) This is a well-known fact.

(*b*) The specimen was given a small but definite initial polarization in a known direction. The capacitance was then found to increase the polarization in the same direction. The capacitance was removed and the initial polarization was reversed. When the capacitance was again connected, the polarization was increased in this reverse direction.

(*c*) The approximate reactance of the secondary winding at 100 cycles per sec. was determined from the known data at 50 cycles per sec. and was found to be 13 400 Ω. The value of capacitance to give resonance at 100 cycles would therefore be $0 \cdot 119\ \mu F$. Making allowance for the conditions of test, this is sufficiently close to the value of $0 \cdot 1\ \mu F$, which caused strong polarization, to indicate that the polarization occurred under a condition of resonance with the second harmonic.

(*d*) The wave-form of the secondary voltage with the capacitance connected is shown in Curve *a*, Fig. 24. Even harmonics are indicated, the second being prominent. The two similar specimens (F and F1) were connected in series as shown in Fig. 25, the secondaries being connected in opposition so that the fundamental and odd harmonics cancelled out. The polarization in each specimen was arranged to be in such a direction that the even harmonics were added and were therefore shown on the oscillograph separated from the fundamental and odd harmonics. The even-harmonic content is shown in Curve *b*, Fig. 24, the second harmonic being very prominent.

The primary current wave is shown in Curve *c*, Fig. 24, and the voltage wave without capacitance in Curve *d*.

Fig. 26 shows the loop formed by the 50-cycle primary current and the even-harmonic voltage. The even-harmonic amplitude in this loop and in Curve *b*, Fig. 24, is twice that for a single specimen (F or F1), owing to the even-harmonic voltages of the two specimens being added, as described.

(*e*) Specimen F (E.S. stalloy) and Specimen C (mumetal) were connected as shown in Fig. 27, the stalloy specimen being used as a transformer to supply magnetizing current to the mumetal specimen, and means were provided as shown for polarizing the stalloy with

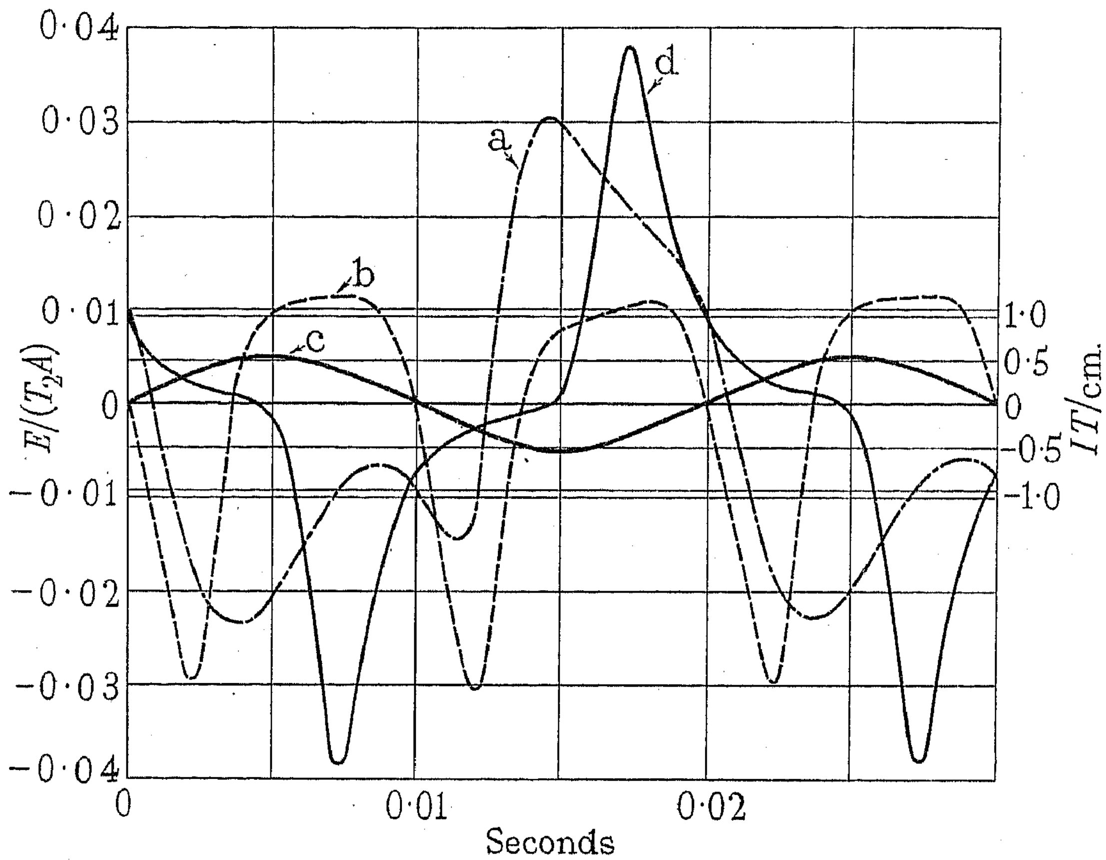


Fig. 24

direct current. The magnetizing current for the mumetal specimen thus contained even harmonics. Care was taken that the mumetal specimen was in a non-polarized condition prior to this test. With potentiometer P at zero, switch S was closed, then S_1. The poten-

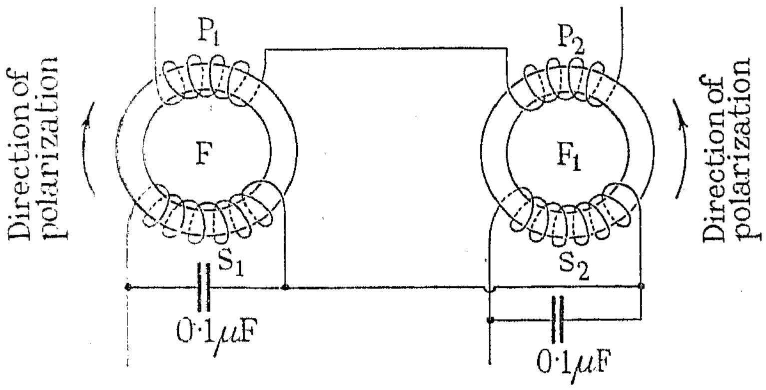


Fig. 25

tiometer was then adjusted until $(IT)_m$ for the mumetal specimen was 0·124. The current was then reduced slowly to zero; S_1 was opened, and then S. The mumetal specimen was then tested for residual polarization and found to be polarized. The order of closing and opening switches S and S_1 in the above test is important in order to avoid Specimen C being polarized by a transient when the d.c. supply to Specimen F is made or broken. It may also be pointed out that any distortion of output from the main transformer T does not affect the validity of the test, as the object is to show that when a current containing even harmonics is used to magnetize Specimen C this specimen becomes polarized.

An air-core transformer was then substituted for the mumetal specimen in Fig. 27; with the stalloy specimen polarized, an E–I loop for the air-core transformer showed marked asymmetry due to the even harmonics in the magnetizing current. It is clear, however, that under these conditions there was no polarization of the air core. In any case, polarization of an air core would not produce asymmetry. The point of this experiment is that an asymmetrical E–I loop does not necessarily show

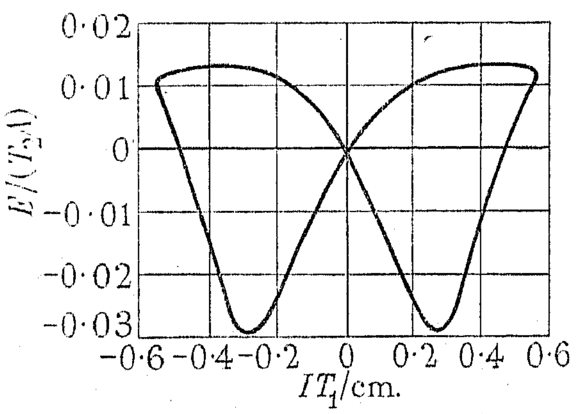


Fig. 26

polarization. It may merely show even harmonics in the magnetizing current. If even harmonics are known to be absent from the magnetizing current, as they usually are, then their presence in the secondary voltage, as shown by an asymmetrical loop, indicates polarization. It should also be noted that Curve *b*, Fig. 19, for stalloy shows that a symmetrical loop does not necessarily indicate the absence of polarization.

The remarks with reference to an air-core transformer do not, of course, alter the fact that even harmonics will cause polarization of some materials, as proved by the foregoing experiments.

A further test to settle this matter was made by utilizing a thermionic-valve amplifier to supply the magnetizing current via a transformer to a mumetal specimen. Any overloading of the valve, thus giving rise to even harmonics, was found to polarize the specimen.

(14) PRODUCTION OF SUB-HARMONICS

Further tests with other values of capacitance and sinusoidal magnetizing current showed that under certain conditions sub-harmonics were produced. This occurred only in the mumetal specimens when a specimen already polarized was loaded with a certain value of capacitance. The effect could be increased greatly by strong polarization with direct current. Fig. 28(*a*)

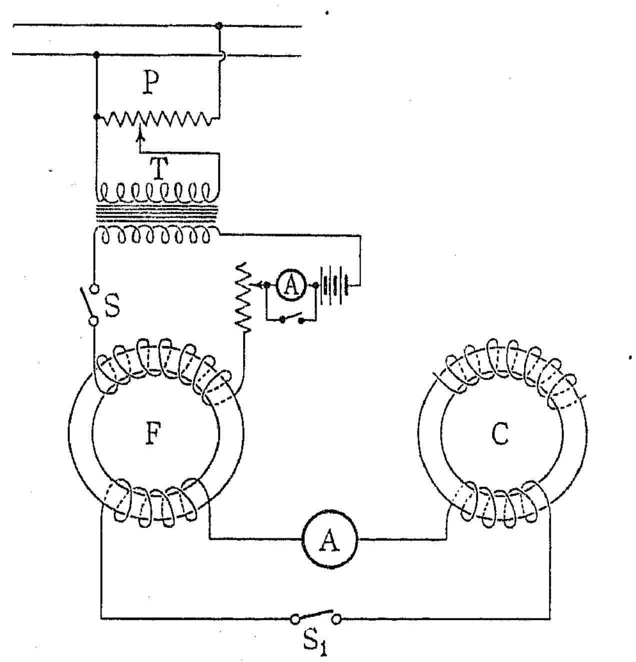


Fig. 27

shows this effect, using Specimen A. The sinusoidal primary current gave $(IT)_m = 0{\cdot}21$, the d.c. polarizing ampere-turns per cm. were 0·12, and the capacitance across the secondary winding was 1·0 μF. The voltage wave-form is shown in Fig. 28(*b*), and a strong 25-cycle sub-harmonic is indicated.

(15) ANOTHER CAPACITANCE EFFECT

Another effect due to capacitance, which has really nothing to do with polarization but is included here as a matter of interest, is shown in Fig. 29. This indicates the effect on Specimen B of raising $(IT)_m$ from 0·270 to 0·274 (Loops *a* and *b* respectively) with 0·2 μF connected across the secondary. Fig. 30 shows $E_{mean}/(T_2A)$ plotted against $(IT)_m$ for these conditions, where

$$\frac{E_{mean}}{T_2A} = \frac{\text{Mean secondary volts}}{\text{Secondary turns} \times \text{Core cross-section}}$$

It will be noticed that a sudden change in the value of E occurs at a critical value of $(IT)_m$.

Some effects of combining capacitances and iron-cored inductances have been dealt with elsewhere at con-

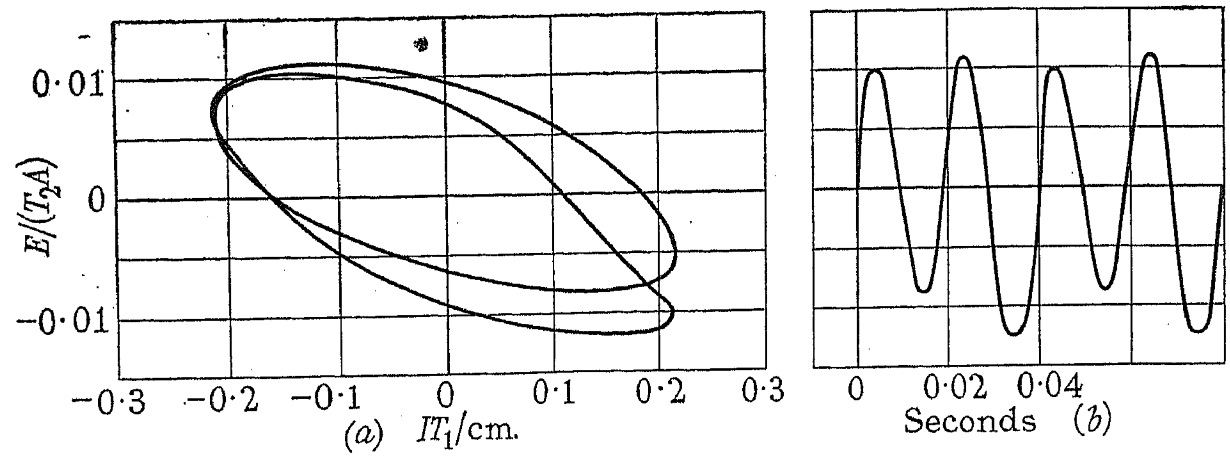


Fig. 28

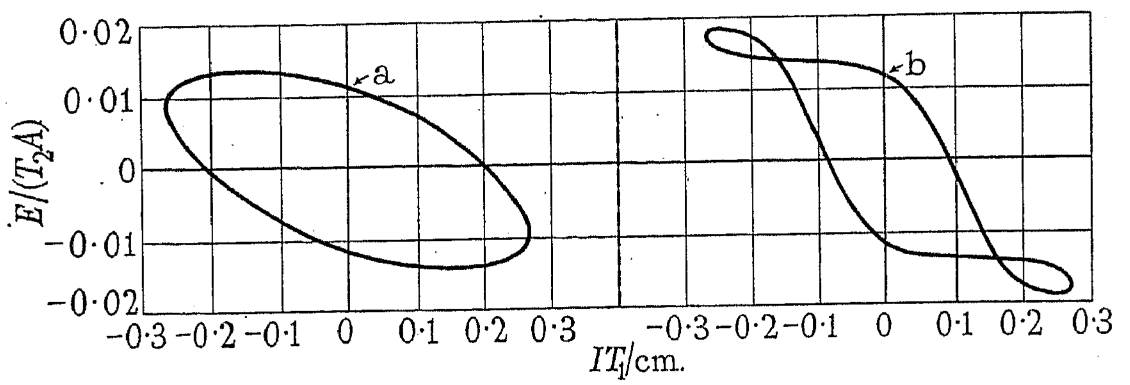


Fig. 29

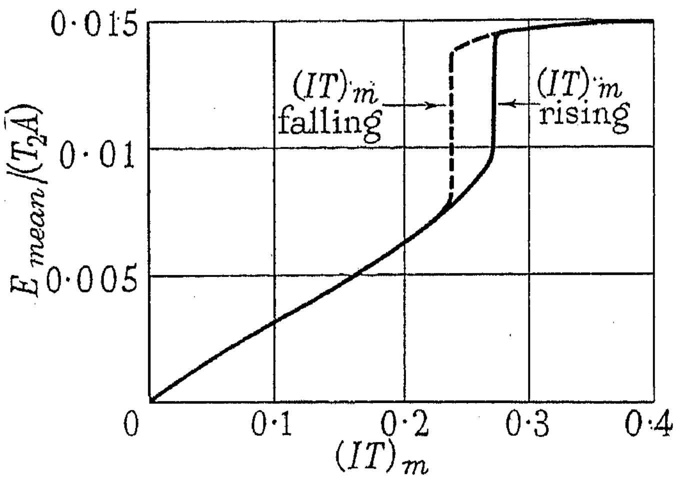


Fig. 30

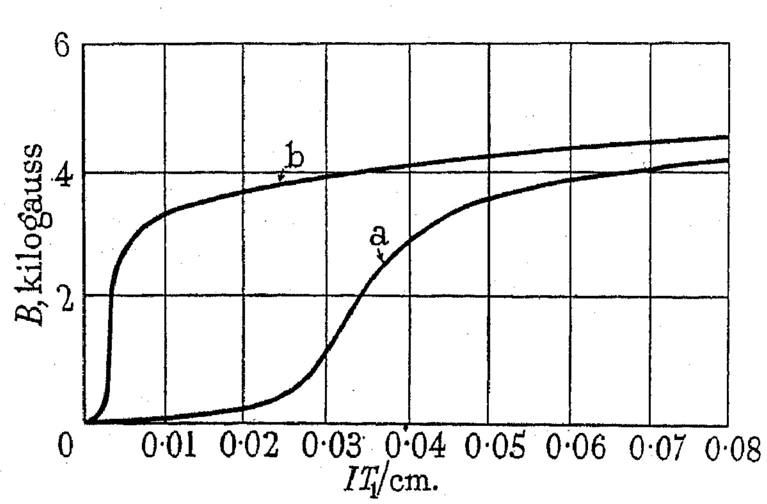


Fig. 31

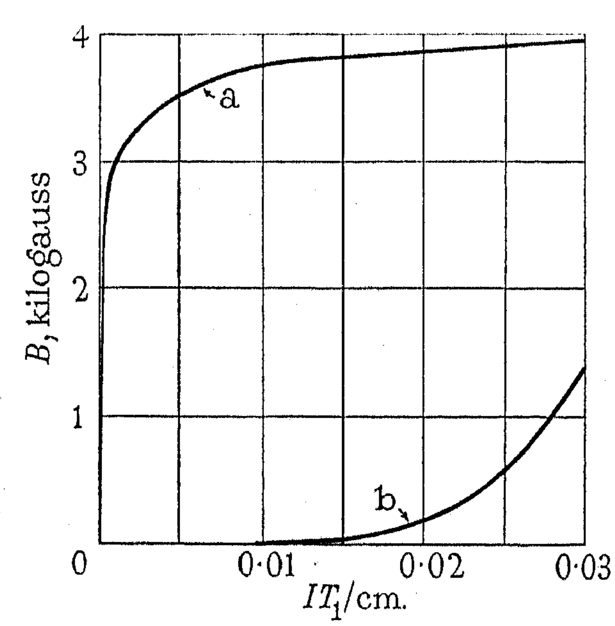


Fig. 32

siderable length,* and a similar effect to the one just described has been noted with modifications of the circuit.

(16) EFFECT OF SUPERIMPOSED ALTERNATING CURRENT ON DIRECT-CURRENT MAGNETIZATION CURVES

The effect of superimposing an a.c. magnetizing force on a specimen while the d.c. magnetization curve is plotted has been dealt with elsewhere,† and it has been found that the d.c. flux density is increased considerably at low values of magnetizing force when alternating current of a suitable value is superimposed. Such a curve for Specimen A (mumetal) is shown in Curve *b*, Fig. 31. The superimposed alternating current had a value which gave $(IT)_m = 0 \cdot 072$. Curve *a*, Fig. 31, is the normal d.c. magnetization curve.

Curve *a*, Fig. 32, is the residual polarization curve for the same specimen which resulted from d.c. magnetization when alternating current of a fairly high value—$(IT)_m = 0 \cdot 32$—was superimposed and reduced slowly to zero each time before the direct current was switched off. The normal residual polarization produced by switching off direct current over the same range of H is shown by Curve *b* in the same Figure. Similar effects have been observed in the case of other ferromagnetic materials.‡

* *Transactions of the American I.E.E.*, 1931, vol. 50, p. 724; and 1932, vol. 51, p. 914.
† *Transactions of the American I.E.E.*, 1933, vol. 52, p. 721.
‡ "Encyclopaedia Britannica," 14th ed., vol. 14, p. 660.

(17) CONCLUSION

It is beyond the scope of the present paper to deal in detail with the bearing of these phenomena on the design of magnetic apparatus, but it is clear that many of the phenomena described should be taken into account in the design and operation of transformers and chokes, particularly when used for instrument and communication work. It should be pointed out, however, that most of the tests were made on plain ring stampings, and that polarization phenomena are most marked with this form of core, owing to the excellent iron circuit. Plain ring stampings of nickel-iron alloys are seldom used nowadays on account of their cost, but the more usual strip-wound core exhibits these phenomena to quite a marked degree. This is evident in the asymmetrical Loop *b* shown in Fig. 16 for Specimen C. It is to be expected that other forms of core, such as those made up of E stampings or T and U stampings, would be less susceptible to residual polarization, and in the case of E stampings made of permalloy "C" (Specimen E) it was found impossible to obtain asymmetrical loops except with a permanently superimposed d.c. magnetizing force (see Fig. 18).

The author wishes to thank Dr. E. Hughes for the loan of mumetal specimens and for his constant encouragement during the experimental work described in this paper. He also wishes to thank Messrs. Standard Telephones and Cables, Ltd., for supplying permalloy specimens; and Messrs. Joseph Sankey and Sons, Ltd., for supplying stalloy specimens.

[The discussion on this paper will be found on page 139.]

THE USE OF AUXILIARY CURRENT-TRANSFORMERS FOR EXTENDING THE RANGE OF METERING EQUIPMENT

By G. F. SHOTTER, Member.*

(*Paper received* 25*th February*, 1938; *read before the* METER AND INSTRUMENT SECTION 1*st April*, 1938.)

SUMMARY

The paper deals with methods of extending the normal range of alternating-current metering equipments.

The various methods which have hitherto been available for the purpose are first mentioned, and the reasons for their not having been brought into general use are briefly indicated.

Results of an investigation employing small auxiliary transformers are then given, and details of the design and performance of such transformers are stated. Reference is also made to the methods of compensation which were used to overcome errors encountered under certain conditions, particularly in the case of low-grade main current-transformers. Finally, it is shown that the method is capable of giving accurate results over a range of 80/1 instead of the normal range of 20/1.

INTRODUCTION

It is always a difficult task to predetermine the most suitable rating for large metering equipments, because trade cycles and the vagaries of industrial power demands generally can cause such wide variations in the load. As is known, these conditions often necessitate frequent changes in current transformers to prevent excessive temperature-rise and to ensure that meter torques and maximum-demand readings are adequate. Indeed, the author has frequently had experience of cases in which the load demands varied so erratically that the current transformers had to be changed annually. The expense entailed in making such changes is considerable, quite apart from the inconvenience caused to consumers. This is especially so in the case of high-voltage supplies, where the transformers are frequently embedded in chambers forming an integral part of the main switchgear. The same problem arises in the case of substation " efficiency " meters, but here accuracy is often sacrificed to expediency, and modifications are not made until overload considerations render them essential.

It follows, therefore, that a simple method whereby the effective ranges of the metering equipments could be altered on site by merely changing the terminal connections would prove extremely advantageous. The main object of this short paper is to put forward a method which has been developed to achieve this purpose. This method was made possible by the advent of mumetal, and in practice it has been found to overcome successfully most of the difficulties associated with the problem.

RANGE-CHANGING METHODS AVAILABLE

A number of methods are available by means of which the effective ratios of the current transformers or the ratings of the meters can be altered without the necessity of removing the apparatus. They all suffer, however, from some disadvantage which prevents them from becoming generally used. The methods are as follows:—

(*a*) Multi-wound meter coils with series-parallel connection.

(*b*) Current transformers with series-parallel or tapped primary windings.

(*c*) Current transformers with tapped secondary windings.

Method (*a*) gives accurate results if suitably applied, but it calls for the use of a non-standard meter, plus a complicated meter coil and series-paralleling device. It is also clear that the burden on the secondary of the current transformers varies with the range employed.

Method (*b*) suffers from mechanical defects in that it presents manufacturing difficulties, particularly where the reduction of the ratio required is of the order of, say, 4/1.

Method (*c*) has been used to some extent and can give good results, especially with modern transformers, but where more than two ranges are required the trouble and expense of tapping the secondary winding has apparently prevented it from becoming popular. A point which should also be borne in mind is that the burden rating of the current transformer is altered with each tapping, and consequently a fixed burden produces different ratio and phase-angle errors for each range.

A RANGE-CHANGING METHOD FOR GENERAL USE

In seeking a range-changing method for general use, several points had to be taken into consideration. A feature which seemed essential was that the method should take the form of an auxiliary device which would be directly applicable to existing metering equipments without calling for modifications in the design of meters and current transformers. Another point which arose was that the device, if possible, should not necessitate an extension of the errors allowed by existing standard specifications over the increased number of ranges. Finally, the fact that it should not add too much to the overall cost of the equipment had to be borne in mind.

After considering these restrictions, it was decided to experiment with a method consisting of the use of a multi-range step-up transformer connected between the secondary of the main current-transformer and the meter. In itself, the idea underlying this method is simple, but the research work involved in its application has been considerable and the results so far obtained would seem to prove that the method is of value. As is known, such a method has not been feasible hitherto,

* North Metropolitan Electric Power Supply Company.

Table 1

COMPARISON BETWEEN AUTO AND DOUBLE WINDINGS ON AUXILIARY TRANSFORMER NO. 5

Double-Wound Connection

Primary current	5/5 range		2·5/5 range		1·25/5 range	
	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes
100	1/0·994	8 +	0·5/0·994	9 +	0·25/0·996	8 +
50	1/0·993	12 +	0·5/0·993	11 +	0·25/0·996	11 +
20	1/0·992	23 +	0·5/0·992	21 +	0·25/0·995	23 +
10	1/0·991	28 +	0·5/0·992	28 +	—	—
5	1/0·989	32 +	—	—	—	—

Auto Connection

Primary current	5/5 range		2·5/5 range		1·25/5 range	
	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes
100	1/0·996	4 +	0·5/0·995	6 +	0·25/0·997	7 +
50	1/0·995	9 +	0·5/0·994	10 +	0·25/0·996	10 +
20	1/0·995	13 +	0·5/0·993	18 +	0·25/0·996	20 +
10	1/0·993	17 +	0·5/0·992	23 +	—	—
5	1/0·992	25 +	—	—	—	—

Volt-Ampere Burden Measured at Primary Terminals

Range	Auto	Double	Difference
5/5	<1	2·0	1·0
2·5/5	4·0	7·5	3·5
1·25/5	25	30	5·0

Burden on secondary = 0·8 VA.

Table 2

CHARACTERISTICS OF AUXILIARY TRANSFORMER TYPE RB: AUTO CONNECTION

Primary current	5/5 range		2·5/5 range		1·25/5 range	
	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes
100	1/0·993	4 +	0·5/0·992	6 +	0·25/0·993	7 +
50	1/0·993	7 +	0·5/0·992	9 +	0·25/0·993	10 +
20	1/0·991	13 +	0·5/0·990	15 +	0·25/0·993	17 +
10	1/0·989	21 +	0·5/0·988	23 +	—	—
5	1/0·987	23 +	—	—	—	—

The primary and secondary burdens were as follows: 5/5 range, < 1 VA (primary), 0·8 VA (secondary); 2·5/5 range, 4·0 VA (primary), 0·8 VA (secondary); 1·25/5 range, 22·0 VA (primary), 0·8 VA (secondary).

owing to the comparatively high losses of transformers manufactured with available materials. The development of mumetal, however, has made the method possible, and once a satisfactory auxiliary transformer had been designed the next step consisted in ascertaining the overall performance which could be obtained when using it in conjunction with various grades of main current-transformers and with different values for the step-up ratios.

While the work described in this paper can be said to cover the problem adequately, there are possibilities in the use of the method which have yet to be fully investigated.

DESIGN OF THE AUXILIARY CURRENT-TRANSFORMER

The decisive feature of the auxiliary transformer would necessarily be the impedance measured at its primary terminals with the secondary load connected. It should also have reasonably low errors over the usual range of currents from full load to 1/20th full load. Unfortunately, these characteristics are conflicting, since with a given core-size an improvement in one can only be obtained at the expense of the other. In other words, if more ampere-turns are added or the core dimensions increased to improve the accuracy of the auxiliary transformer, its primary burden is increased and thus the errors of the main transformer due to this burden are correspondingly increased. A compromise has therefore to be made in order to obtain the best overall results.

The desired accuracy at the required volt-ampere output (approximately 1·0 VA) was obtained by giving consideration to the usual features of design, and with the use of mumetal. The impedance characteristic was a more difficult proposition, and a number of experimental transformers having various core dimensions and arrangements of windings were made to obtain a minimum value for this figure commensurate with small ratio and phase-angle errors. One experimental transformer which was developed was made suitable for either auto or double-wound connections; the general arrangements of the two types of winding are shown in Fig. 1. Table 1 gives a comparison between the results obtained with the auto and double windings. It should be borne in mind that in both cases the same core and the same windings, differently connected, were used. From Table 1, it will be observed that a gain in the burden imposed on the main current-transformer is obtained with the auto connection and that there is also a slight gain in overall accuracy, particularly in angle. Further, the agreement between the ranges is fairly close, and it is probably within possible experimental errors. It will be appreciated that the testing of individual ranges presents some difficulties.

The final development of the small auxiliary trans-

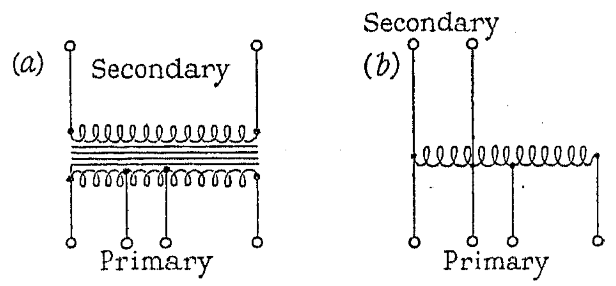


Fig. 1

(a) Double-wound auxiliary transformer.
(b) Auto-type auxiliary transformer.

former took the form of a shell-type core with a distributed auto-type winding having an ampere-turn rating of 120. The core dimensions were as follows: Overall length $2\frac{3}{16}$ in., overall width $1\frac{7}{8}$ in., stack height $\frac{5}{8}$ in., winding space $\frac{1}{2}$ in. × $1\frac{1}{4}$ in.

The results of the test made with the transformer are given in Table 2.

OVERALL ACCURACY

The practical limit of the step-up ratio and the overall accuracy obtainable with this auxiliary transformer when used in conjunction with various types of commercial transformers had next to be ascertained.

Test results are given for three grades of main current-transformers, these being representative of a larger number taken to elucidate this aspect of the problem. In each instance, the auxiliary multiplying current-transformer had ratios of 1·25/5, 2·5/5, and 5/5. A step-up ratio of 1/5 was successfully used in particular cases

Table 3

CHARACTERISTICS OF CURRENT TRANSFORMER NO. 1 (1 000/5)

Primary current	A		B		C		D		E	
	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes		minutes		minutes
120	200/1·003	1−	200/0·998	29+	200/1·003	2−	—	—	—	—
60	200/1·003	2−	200/0·999	18+	200/1·003	2−	200/1·002	0	—	—
24	200/1·003	4−	200/0·999	13+	200/1·003	3−	200/1·002	2−	200/1·000	0
12	200/1·003	4−	200/0·998	14+	200/1·003	4−	200/1·002	2−	200/0·999	0
6	200/1·002	1−	200/0·997	21+	200/1·002	0	200/1·001	4+	200/0·998	6+

The values of the burden on the secondary of the transformer were as follows: Test A, 6 VA (non-inductive); Test B, 45 VA (non-inductive); Test C, auxiliary transformer, 5/5 range + 6 VA = 7 VA; Test D, auxiliary transformer, 2·5/5 range + 6 VA = 10 VA; Test E, auxiliary transformer, 1·25/5 range + 6 VA = 28 VA. Burden on the secondary of the auxiliary transformer, 0·8 VA.

Table 4

OVERALL ERRORS OF TRANSFORMER NO. 1 (SEE TABLE 3) AND AUXILIARY TRANSFORMER TYPE RB (SEE TABLE 2)

Primary current (main c.t.)	Auxiliary-transformer range 5/5	
	Ratio	Angle
%		minutes
120	200/0·997	3 +
60	200/0·996	5 +
24	200/0·995	10 +
12	200/0·994	13 +
6	200/0·992	25 +

Primary current (main c.t.)	Auxiliary-transformer range 2·5/5	
	Ratio	Angle
%		minutes
60	100/0·995	8 +
30	100/0·995	8 +
12	100/0·994	14 +
6	100/0·993	24 +
3	100/0·992	29 +

Primary current (main c.t.)	Auxiliary-transformer range 1·25/5	
	Ratio	Angle
%		minutes
30	50/0·992	16 +
15	50/0·992	16 +
6	50/0·990	27 +
3	50/0·989	37 +
1·5	50/0·987	45 +

Table 5

CHARACTERISTICS OF CURRENT TRANSFORMER NO. 2 (200/5)

Primary current	A		B		C		D		E	
	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes		minutes		minutes
100	40/1·007	0	40/1·006	11+	40/1·007	2+	—	—	—	—
50	40/1·005	2+	40/1·004	16+	40/1·005	4+	40/1·005	6+	—	—
20	40/1·001	4+	40/1·000	28+	40/1·001	7+	40/1·000	10+	40/0·997	21+
10	40/0·998	8+	40/0·995	40+	40/0·997	13+	40/0·996	15+	40/0·992	32+
5	40/0·993	13+	40/0·989	59+	40/0·992	19+	40/0·990	26+	40/0·984	49+

The values of the burden on the secondary of the transformer were as follows: Test A, 6 VA (non-inductive); Test B, 31 VA (non-inductive); Test C, auxiliary transformer, 5/5 range + 6 VA = 7 VA; Test D, auxiliary transformer, 2·5/5 range + 6 VA = 10 VA; Test E, auxiliary transformer, 1·25/5 range + 6 VA = 28 VA. Burden on the secondary of the auxiliary transformer, 0·8 VA.

Table 6

OVERALL ERRORS OF A METER CONNECTED TO CURRENT TRANSFORMER NO. 2 (SEE TABLE 5) AND AUXILIARY TRANSFORMER NO. 5: AUTO CONNECTIONS (SEE TABLE 1)

Power factor	Unity					0·5 lagging			
With 5/5 range of auxiliary transformer (equivalent to 200/5 meter)									
Primary current (main c.t.), per cent	100	50	20	10	5	100	50	20	10
Meter load, per cent	100	50	20	10	5	50	25	10	5
Meter errror, per cent	2·0+	1·4+	1·5+	1·6+	1·4+	1·4+	1·0+	±	0·8+
With 2·5/5 range of auxiliary transformer (equivalent to 100/5 meter)									
Primary current (main c.t.), per cent	50	25	10	5	2·5	50	25	10	5
Meter load, per cent	100	50	20	10	5	50	25	10	5
Meter error, per cent	1·6+	1·0+	1·0+	1·0+	0·5+	1·6−	0·6−	0·1+	0·9+
With 1·25/5 range of auxiliary transformer (equivalent to 50/5 meter)									
Primary current (main c.t.), per cent	25	12·5	5	2·5	1·25	25	12·5	5	2·5
Meter load, per cent	100	50	20	10	5	50	25	10	5
Meter error, per cent	0·9+	0·1+	0·2−	0·7−	1·6−	1·5−	0·6−	±	1·3+

where tne characteristics of the main current-transformers were suitable.

The main current-transformer in the first test was a bar-primary 1 000-ampere instrument of modern design having a hybrid core, supplied by the manufacturers for ordinary industrial metering. The performance, shown in Table 3, is extremely good, and tests which have been made indicate that the errors down to 1/80th full load are very little in excess of those over the range given. As will be seen, the transformer is within the limits of accuracy laid down in B.S.S. No. 81—1936 for Class AM metering transformers. The various burdens imposed on the main current-transformer with a meter coil connected to the auxiliary transformer are shown in the lower part of the Table.

Table 4 shows the overall errors of the combined main current-transformer and auxiliary transformer, a point to be noted being that the errors are well within the usual tolerances for high-grade metering. It would seem that no difficulty should be experienced in adjusting a meter connected in circuit to an accuracy of within 1 % on all ranges. This is equivalent to ratios of 1 000/5, 500/5, and 250/5 on loads from 120 % to 6 % of full load, with power factors from unity to 0·5 on the three ranges. In other words, this is the equivalent of a range of load of 80/1 on the main current-transformer, 20/1 on the auxiliary transformer, and 20/1 on the meter. It is to be noted that on the 5/5 range there is a 0·5 % change in overall ratio-error and a 22-minute change in overall angle-error. In the 2·5/5 case the change is approximately the same, and in the 1·25/5 case a 0·5 % change in overall ratio-error and a 29-minute change in overall angle-error occur. Another point is that the difference in the mean error between ranges is also small.

Table 7

Characteristics of Transformer No. 3 (200/5)

Primary current	6 VA (non-inductive)		15 VA (non-inductive)	
	Ratio	Angle	Ratio	Angle
%		minutes		minutes
100	40/1·005	15 +	40/1·003	29 +
50	40/1·002	27 +	40/1·000	43 +
20	40/0·998	40 +	40/0·997	62 +
10	40/0·995	49 +	40/0·993	74 +
5	40/0·989	59 +	40/0·988	90 +

The foregoing test shows that as far as the latest types of current transformers are concerned no difficulties should arise in the use of the method. The next point to be considered related to the degree of accuracy obtainable in the case of existing current-transformers, the errors of which are often considerably in excess of those mentioned above. A test was therefore made on a silicon-steel current-transformer with various burdens, as shown in Table 5. This transformer had characteristics which are typical of a large number of transformers at present used for metering large consumer's loads. In this case, the procedure was to connect a standard induction meter to each of the three ranges of the auxiliary transformer in turn, the meter being adjusted to give minimum overall errors, as shown in Table 6. As will be seen, the meter was made to conform with the performance laid down by the current B.S.S. No. 37.

Current transformers having errors which approximate to the maximum allowed by B.S.S. No. 81—1927 (Class "B" accuracy) were next considered (Table 7). The same test procedure as that described above was carried out, the overall error of the main and auxiliary transformers being measured by connecting a meter to each range in turn. It is fairly obvious that even when this type of main transformer is used the difficulties only became serious on the 1·25/5 range. The lowest set of curves shown in Fig. 2 illustrate, however, that a meter

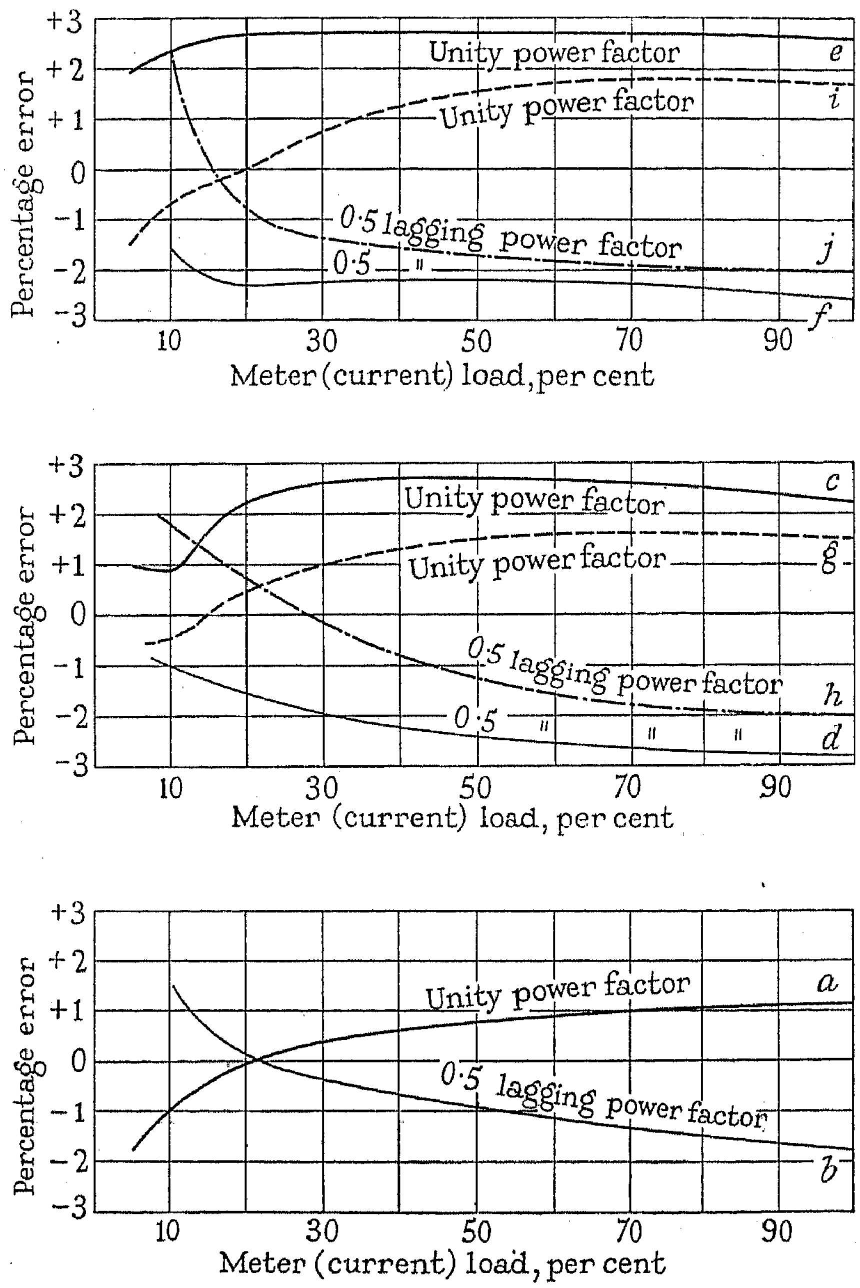


Fig. 2.—Overall errors of a meter connected to current-transformer No. 3 (Table 7) and the auxiliary transformers of Table 2, showing effect of series-impedance compensation (Fig. 3).

Case 1 (top curves): With 5/5 range of multiplying current-transformer (equivalent to 200/5-ampere equipment).
Case 2 (middle curves): With 2·5/5 range of multiplying current-transformer (equivalent to 100/5-ampere equipment).
Case 3 (lower curves): With 1·25/5 range of multiplying current-transformer (equivalent to 50/5-ampere equipment).
———— Without compensation. - - - - - With compensation.

can be calibrated to be within a $\pm$ 2 % error band even on this range, although the errors on the other ranges then become too large. On the other hand, it will be seen later that a meter can be calibrated to be within a $\pm$ 1 % error band on the other two ranges when this type of main current-transformer is used. Consequently it was decided to ascertain whether the mean error between the various ranges could be decreased and whether it was possible to improve the error slope by some simple method of compensation.

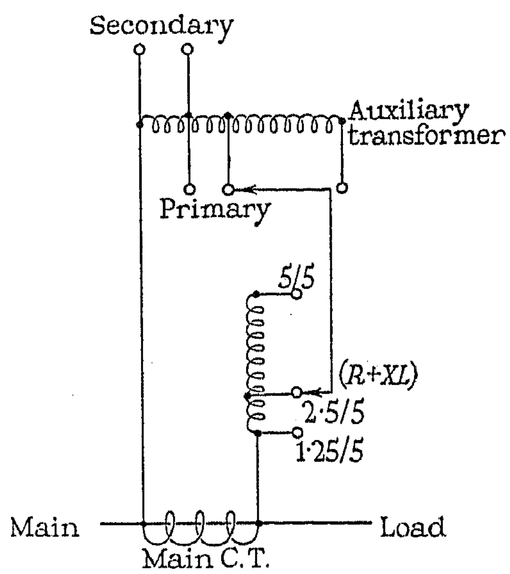


Fig. 3.—Compensation by series-impedance method.

METHODS OF COMPENSATION

Four methods of compensation were considered:—

(*a*) Series-impedance method (Fig. 3).
(*b*) Resistive shunt connected across the secondary terminals of the main current-transformer (Fig. 4).
(*c*) Capacitive shunt connected across the secondary terminals of the main current transformer (Fig. 5).
(*d*) As (*c*), together with turns compensation added to the primary winding of the auxiliary transformer on the 1·25/5 range (Fig. 6).

Method (a)

Method (*a*) consisted of an attempt to equalize the characteristics of the main current-transformer by adding series burden to its secondary when the 2·5/5 and 5/5 ranges of the auxiliary transformer were in use. The impedance used was set at a fixed optimum value for the tests on the 2·5/5 range and at a higher fixed optimum value for tests on the 5/5 range, the meter being adjusted to give minimum errors on the 1·25/5 range. The results are shown in Fig. 2, Curves *a* to *j*. It will be seen that

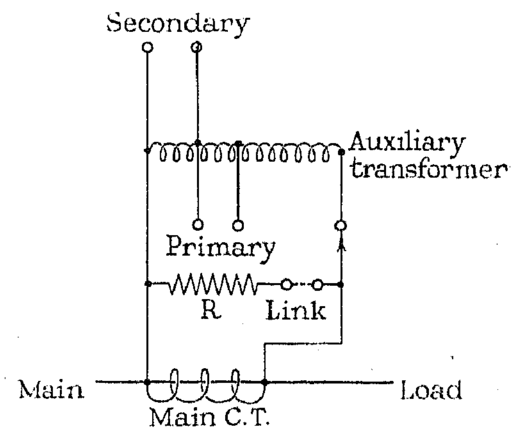


Fig. 4.—Resistance compensation.

whilst a reduction in the difference between the mean errors of the various ranges is obtained, the gain in this respect is discounted by the unequal distortion of the error curves, and for this reason the method was abandoned.

More familiar methods of compensation by means of various kinds of shunts connected across the secondary terminals of the main current-transformer were then investigated. It is to be noted that this type of compensation was only applied to the 1·25/5 range (see Figs. 4, 5, and 6).

Methods (b), (c), and (d)

H. W. Price and C. K. Duff have investigated the reduction in ratio and phase-angle by means of the use of shunts connected across the terminals of current trans-

Table 8

OVERALL ERRORS OF CURRENT TRANSFORMER NO. 3 (TABLE 7) AND OF THE AUXILIARY TRANSFORMER OF TABLE 2 (1·25/5 RANGE), SHOWING EFFECT OF RESISTIVE COMPENSATION SHUNTS

Primary current (main c.t.)	A		B		C		D		E	
	Uncompensated		$r_c = 20\ \Omega$		$r_c = 10\ \Omega$		$r_c = 9\ \Omega$		$r_c = 8\ \Omega$	
	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes		minutes		minutes
25	10/0·980	100+	10/0·938	61+	10/0·898	26+	10/0·890	19+	10/0·877	10+
12·5	10/0·974	136+								
5	10/0·963	192+								
2·5	10/0·956	206+	10/0·914	176+	10/0·876	144+	10/0·868	138+	10/0·858	130+
1·25	10/0·941	—								

formers, and have shown that to a first approximation the following relationships hold:—

Non-inductive shunts.

The ratio of the current transformer is increased by

$$\frac{R_s}{r_c} \times 100\ \% \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (1)$$

The positive angle is reduced by

$$\text{arc tan}\,\frac{X_s}{r_c} \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (2)$$

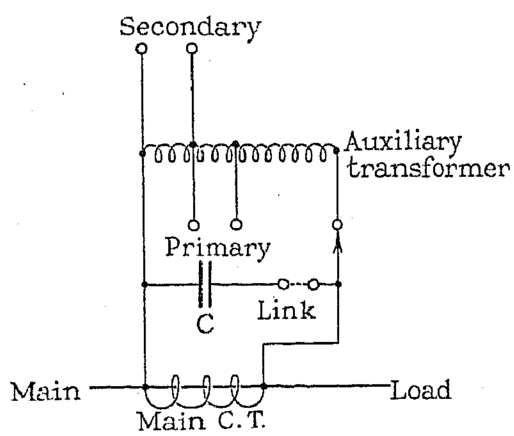


Fig. 5.—Capacitance compensation.

where R_s and X_s are the resistance and reactance respectively of the secondary burden, and r_c is the resistance of the non-inductive shunt.

Capacitive shunts.

The ratio is reduced by

$$X_s C\omega \times 100\ \% \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (3)$$

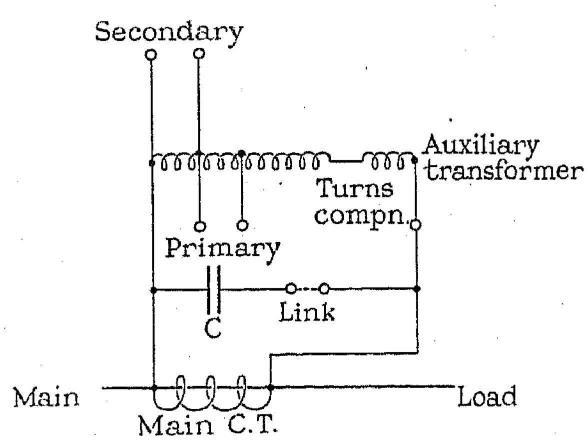


Fig. 6.—Capacitance and turns compensation.

The positive phase-angle is reduced by

$$\text{arc tan}\,R_s C\omega \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad (4)$$

where C is the capacitance of condenser (in farads) and $\omega = 2\pi \times$ frequency.

It follows from the above that, for non-inductive resistance compensation, an appreciable reduction in angle can only be obtained without seriously affecting the ratio with a secondary burden having a power factor approxi-

Table 9

OVERALL ERRORS OF CURRENT TRANSFORMER NO. 3 (TABLE 7) AND OF THE AUXILIARY TRANSFORMER OF TABLE 2 (1·25/5 RANGE), SHOWING EFFECT OF CONDENSER AND TURNS COMPENSATION ON THE AUXILIARY TRANSFORMER

Primary current (main c.t.)	A*		B*		C*		D*		E*		F†		G†		H†	
	No compensation		5 µF		15 µF		29 µF		41 µF		25 µF		75 µF		75 µF + Turns compensation	
	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes		minutes		minutes		minutes		minutes		minutes
25	10/0·980	100+	10/0·981	96+	10/0·982	86+	10/0·984	68+	10/0·985	52+	10/0·983	61+	10/0·990	11−	10/0·999	11+
12·5	10/0·974	136+	10/0·975	130+	10/0·976	118+	10/0·978	102+	10/0·980	82+	10/0·976	100+	10/0·985	25+	10/1·000	38+
5	10/0·963	192+	10/0·964	180+	10/0·966	162+	10/0·967	156+	10/0·970	136+	10/0·966	148+	10/0·976	71+	10/0·998	65+
2·5	10/0·956	206+	10/0·955	200+	10/0·958	200+	10/0·959	180+	10/0·960	162+	10/0·956	172+	10/0·968	106+	10/0·991	100+
1·25	10/0·941	—	—	—	—	—		—	—	—	—	—	10/0·957	—	10/0·979	—

* Paper condensers. † Electrolytic condensers.

mating to zero. Unfortunately, this condition does not appertain to the problem under consideration, and the method is therefore not directly applicable.

The results given in Table 8 indicate the effect of various values of non-inductive shunts (Fig. 4) on the combined errors of the 4/1 range. It will be seen that on 25 % load and 2·5 % load an 8-ohm shunt decreases the mean angle by 83 minutes. The ratio, however, is increased by approximately 10 %.

Resistive shunts would seem to have advantages over other methods, and further investigations are being carried out to explore their possibilities when used in auxiliary transformer and connected in series with the 1·25/5 winding as illustrated in Fig. 6. The effect of the combined capacitance and turns compensation is shown in col. H, Table 9. One or two interesting points are to be noted from a comparison of col. G and col. H of this Table. The first is the reduction in angle-change from 117 minutes to 89 minutes. The second is the improvement in the ratio error with a change of 3·3 % in col. G, to a maximum change of 2·1 % in col. H. Another interesting point is the flattening of the ratio curve at the highest loads. This accounts for the smaller change in ratio.

Table 10

OVERALL ERRORS OF A METER CONNECTED TO CURRENT TRANSFORMER NO. 3 (TABLE 7) AND THE AUXILIARY TRANSFORMER OF TABLE 2, SHOWING EFFECT OF CONDENSER AND TURNS COMPENSATION ON THE 1·25/5 RANGE

Power factor	Unity					0·5 lagging			
With 5/5 range of auxiliary transformer (equivalent to 200/5 meter)									
Primary current (main current-transformer), per cent	100	50	20	10	5	100	50	20	10
Meter load, per cent	100	50	20	10	5	50	25	10	5
Meter error, per cent	0·5+	0·3+	0·1−	0·4−	0·6−	0·4−	0·1−	0·4+	0·5+
With 2·5/5 range of auxiliary transformer (equivalent to 100/5 meter)									
Primary current (main current-transformer), per cent	50	25	10	5	2·5	50	25	10	5
Meter load, per cent	100	50	20	10	5	50	25	10	5
Meter error, per cent	0·5−	0·4−	0·7−	1·1−	2·0−	0·5−	0·4+	0·8+	1·0+
With 1·25/5 range of auxiliary transformer (equivalent to 50/5 meter)									
Primary current (main current-transformer), per cent	25	12·5	5	2·5	1·25	25	12·5	5	2·5
Meter load, per cent	100	50	20	10	5	50	25	10	5
A. Meter error with condenser and turns compensation, per cent ..	0·5+	1·0+	0·8+	0·4−	1·1−	0·9−	0·3+	0·6+	1·9+
B. Meter error with turns compensation only, per cent	0·8−	0·4−	0·8−	2·0−	2·7−	2·7+	3·7+	4·3+	5·1+
C. Meter error with no compensation, per cent	1·6−	1·8−	2·7−	4·0−	4·5−	0·8+	1·5+	2·4+	3·2+

conjunction with turns compensation on the primary of the 1·25/5 range of the auxiliary transformer, an arrangement to compensate for the ratio error produced by the resistive shunt.

The effect of connecting various values of capacitance across the secondary of the main current-transformers when connected to the auxiliary transformer on the 1·25/5 range is shown in Table 9. It will be seen that, in the case of the 75-μF shunt, although the angle-change remains approximately the same, the mean angle error is improved by approximately 100 minutes. This is similar to the result obtained with the non-inductive shunt, with the important difference, however, that the ratio is not increased but is decreased by approximately 1 % and is, if anything, improved in slope.

Extra turns were then wound on one limb of the

Tests were then carried out on a meter with the dual compensation on the 1·25/5 range, while the other two ranges were uncompensated. Table 10 gives a comprehensive survey of the results of this test, and it will be seen that a meter can be calibrated to be within a ± 2 % error band. It should further be noted that there are only two points at which the maximum error occurs, the majority of points being within a ± 1 % band. As a means of comparison, figures are also given showing the meter error with turns compensation and with no compensation. Considering the type of current transformer used, these results would seem to be very satisfactory, since they allow a meter to be calibrated to within the limits of accuracy laid down in the current B.S.S. No. 37. It seems possible that further investigation may result in the obtaining of even smaller errors than those shown.

As a matter of interest, Fig. 7 shows the external appearance of a group of three auxiliary transformers suitable for a 3-phase 4-wire metering equipment, and Fig. 8 shows the current connections of a 3-phase 3-wire meter with auxiliary transformers.

made in manufacturing technique and the production of materials not subject to deterioration. It is considered, therefore, that the condensers should give satisfaction for many years. They will, of course, be kept under observation until this claim is substantiated, or, alternatively, until the best type of condenser is produced for the work.

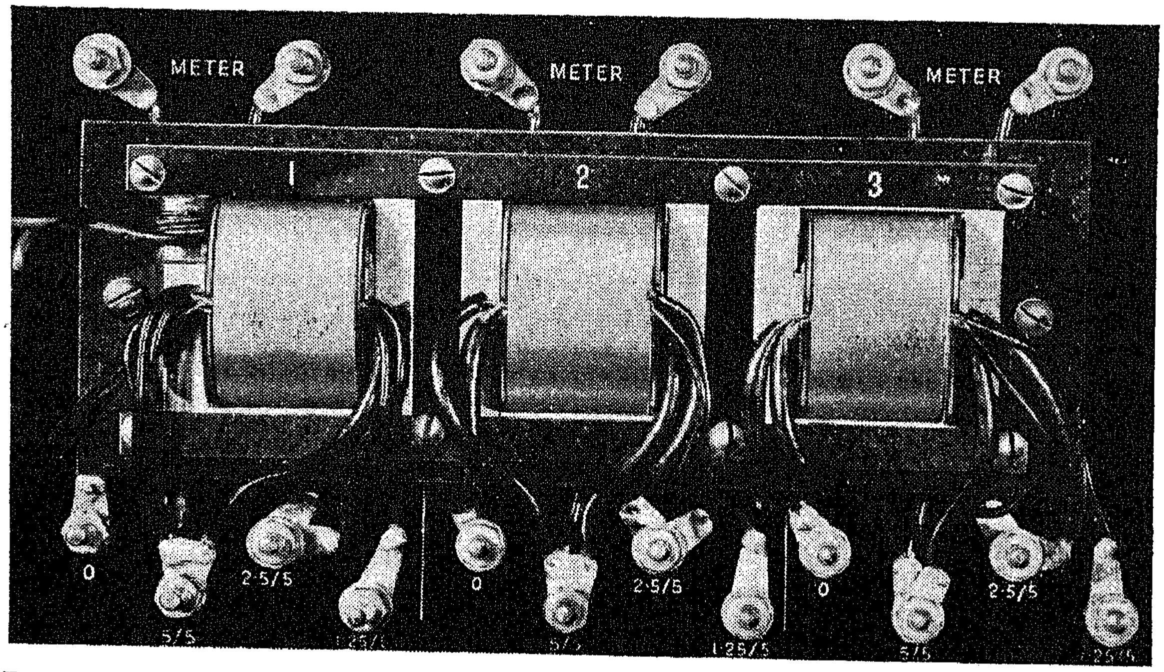


Fig. 7.—External appearance of group of three auxiliary transformers suitable for a 3-phase 4-wire circuit.

COMPENSATING CONDENSERS

The value of the capacitance required for compensating condensers makes the cost and bulk of paper condensers prohibitive for practical purposes. Electrolytic condensers, however, suffer from neither of these disadvantages and have been used with success under laboratory conditions, as is instanced by Tables 9 and 10.

Electrolytic condensers are used in considerable numbers on d.c. circuits, but there appears to be little demand for the type developed for a.c. working, and it is thus rather difficult to obtain data as to their probable behaviour in service. The condensers used in the tests described are rated for continuous use at 12 volts, 50 cycles per sec., approximately 10 times the maximum working voltage, a margin which it is hoped will ensure freedom from breakdown due to voltage surges. Ageing is known to show itself in the form of a falling-off in capacitance and an increase in impedance. The manufacturers claim that both of these defects have been reduced by the great strides which have recently been

CALIBRATION OF THE COMPLETE METERING EQUIPMENT

Laboratory tests follow the usual routine, each range of the meter being tested in turn in conjunction with the auxiliary current-transformers and main current-transformers. Tests on site can be carried out by connecting a substandard meter directly in series with the meter under test. The correct registration is then calculated either by reference to the overall characteristics, such as are shown in Table 4, or, alternatively, by comparing the registration of the meter under test directly with the results of a similar test previously made in the laboratory after adjustment of the meter.

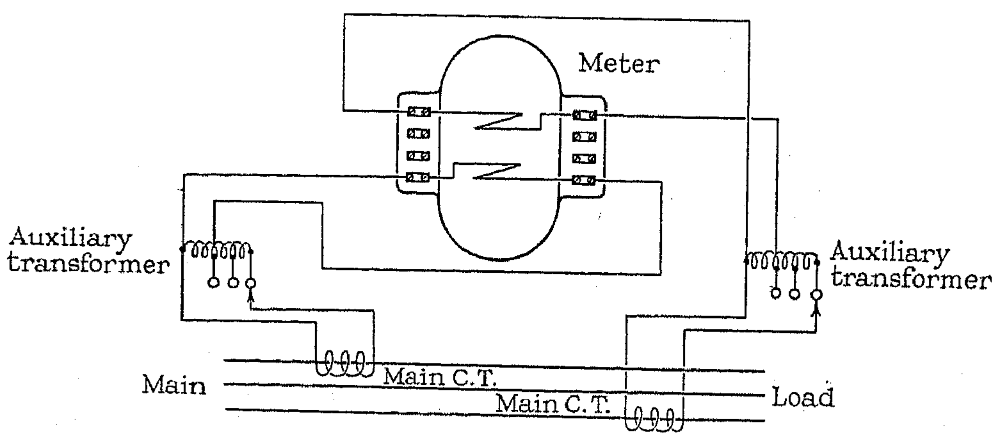


Fig. 8.—Current connections for step-up auxiliary transformers on a 3-phase 3-wire supply.

Testing on site is carried out on the consumer's load and follows the procedure already commonly adopted for testing ordinary metering equipments. A question which might arise relates to the effect of adding a sub-

Table 11

PERCENTAGE CHANGE IN OVERALL METER ERROR DUE TO THE ADDITION OF A SUBSTANDARD METER CONNECTED TO THE SECONDARY OF THE AUXILIARY TRANSFORMER

Primary current (main c.t.)	Auxiliary-transformer range 5/5	
	At unity p.f.	At 0·5 lagging p.f.
%		
100	0·6 —	0·3 —
50	0·3 —	0·5 —
20	0·6 —	0·8 —
10	0·3 —	0·6 —
5	±	—

Primary current (main c.t.)	Auxiliary-transformer range 2·5/5	
	At unity p.f.	At 0·5 lagging p.f.
%		
50	0·5 —	0·7 —
25	0·6 —	0·2 —
10	0·7 —	0·7 —
5	0·8 —	0·6 —
2·5	0·7 —	—

Primary current (main c.t.)	Auxiliary-transformer range 1·25/5	
	At unity p.f.	At 0·5 lagging p.f.
%		
25	0·8 —	0·6 —
12·5	0·5 —	0·5 —
5	0·9 —	0·8 —
2·5	0·8 —	0·4 —
1·25	0·7 —	—

standard meter to the secondary of the auxiliary transformer. Actually, the effect is not so great as might be expected; the change in error due to the addition of the substandard meter connected in series on the secondary side of the auxiliary transformer is given in Table 11. In this case, the main current-transformer had the characteristics shown in Table 5. It will be seen that the change in error both at unity and at 0·5 lagging power-factor is in the majority of cases well within 1 %. Since this error affects both the standard and the meter under test, allowance need not be made for it when the true units are being calculated.

"DIVIDING" CURRENT-TRANSFORMERS

In the measurement of maximum demand, the load sometimes grows so rapidly that although it remains within the thermal rating of the apparatus and the

Table 12

CHARACTERISTICS OF AUXILIARY DIVIDING TRANSFORMERS

No. 1, *ratio* 5/2·5

Primary current	Ratio	Angle	Ratio	Angle	Ratio	Angle
%		minutes		minutes		minutes
100	2/0·997	10 +	2/0·995	18 +	2/0·990	6 +
50	2/0·996	11 +	2/0·994	21 +	2/0·990	2 +
20	2/0·996	19 +	2/0·992	31 +	2/0·987	10 +
10	2/0·995	25 +	2/0·992	40 +	2/0·984	19 +
5	2/0·993	25 +	2/0·990	49 +	2/0·983	25 +
Burdens: Primary ..	0·5 V × 5·0 A = 2·5 VA		0·9 V × 5·0 A = 4·5 VA		1·1 V × 5·0 A = 5·5 VA	
Burdens: Secondary ..	0·6 V × 2·5 A = 1·5 VA*		1·4 V × 2·5 A = 3·5 VA*		1·8 V × 2·5 A = 4·5 VA†	

No. 2, *ratio* 5/3·33

Primary current	Ratio	Angle	Ratio	Angle
%		minutes		minutes
100	1·5/0·997	2 +	1·5/0·989	16 +
50	1·5/0·997	2 +	1·5/0·995	2 —
20	1·5/0·996	5 +	1·5/0·994	0
10	1·5/0·996	5 +	1·5/0·993	5 +
5	1·5/0·996	6 +	1·5/0·992	7 +
Burdens: Measured at primary terminals	0·8 V × 5 A = 4·0 VA		1·8 V × 5 A = 9 VA	
Burdens: Measured at secondary terminals	0·9 V × 3·33 A = 3·0 VA*		2·5 V × 3·33 A = 8·3 VA†	

* Non-inductive. † Inductive.

accuracy is unimpaired, there is a risk of the pointer of the meter moving beyond the full-scale mark. Small auxiliary transformers have been successfully employed in such instances to step down the meter current. Design considerations are comparatively simple, one ratio only being required, and since this is usually not greater than 1·5/1 full advantage of the auto connection is obtained. Also, the problem is not complicated by the main current-transformer working below its normal loads, as in the case of the step-up auxiliary transformer. Table 12 gives the results of tests carried out on two designs of auxiliary dividing current-transformers with various burdens connected. An important point in regard to auxiliary dividing transformers is that the ampere-turn rating can be increased owing to the use of the auto winding, as previously stated. It should be mentioned that the auxiliary transformers used in these tests had the same core dimensions as the auxiliary transformers already described. In the first case, the ratio was 5/2·5 and the ampere-turns 300; in the second case, the ratio was 5/3·33 and the ampere-turns 400. It will be remembered that the ampere-turns of the step-up auxiliary transformer were 120.

Referring to the last columns of the first set of figures in the Table it is interesting to note that even with high secondary burdens such as 4·5 VA (equivalent to 18 VA based on 5 amperes) the change in ratio error is only 0·7 % and the angle-change is only 23 minutes. In this case the secondary burden has a power factor of approximately 0·5, which partly accounts for the improvement in angle shown in these columns as compared with the other two.

From the second set of figures it should be noted that even with the highest secondary burden, namely 8·3 VA (inductive), the corresponding burden measured at the primary terminals of the auxiliary transformer, which is the working burden of the main current-transformer, is only 9 VA.

Indirectly, the use of a step-up auxiliary dividing transformer is conducive to higher accuracy as it allows the maximum-demand attachment to be scaled to a more conservative figure in regard to overload.

CONCLUSION

The main conclusion which can be drawn from the method put forward in this paper is that it is possible to obtain a high degree of accuracy when using good main current-transformers in conjunction with the small auxiliary transformer described. Also, it is possible that further developments by way of improvement in the compensation of the auxiliary transformer will produce even better results than those given here, particularly in regard to the lower classes of main current-transformers. As has been shown with the compensation described in the paper, good commercial accuracy up to at least a 4/1 range can be obtained with low-grade transformers.

An important advantage of the use of the method is that it saves the cost of frequently changing main current-transformers when an increase in load takes place. It is thus particularly useful in the case of substation "efficiency" meters, and especially so where the current transformers are compounded in the switchgear. Two further advantages are that designs of existing transformers and meters do not have to be changed, and also that when the optimum value of the load has been reached, the auxiliary transformers can be used again for other equipment.

Again, the method enables seasonable variations in load to be catered for, and is especially useful in the case of maximum-demand measurement. Another advantage is that by using the method the number of sizes of current transformers which it is necessary to stock can be reduced and thus a saving in the work of clerical and stores staffs can be effected. Finally, the method is simple and comparatively inexpensive.

ACKNOWLEDGMENTS

The author would like to express his thanks to Captain J. M. Donaldson, M.C., general manager of the North Metropolitan Electric Power Supply Co., for permission to publish this paper. Acknowledgments are also due to the author's assistant, Mr. F. G. Talbot, for his valuable help, not only in the experiments, but in the writing of the paper; and to Mr. A. H. Rich, for his assistance in constructing the experimental transformer.

REFERENCES

H. W. Price and C. K. Duff: *University of Toronto Bulletin*, 1921, No. 2.

P. R. Coursey: "Electrolytic Condensers" (Chapman and Hall, 1937).

J. G. Wellings and C. G. Mayo: "Instrument Transformers," *Journal I.E.E.*, 1930, vol. 68, p. 704.

G. F. Shotter: "A New Null Method of Testing Instrument Transformers, and its Application," *ibid.*, 1930, vol. 68, p. 873.

[The discussion on this paper will be found on page 139.]

DISCUSSION BEFORE THE METER AND INSTRUMENT SECTION, 1ST APRIL, 1938, ON THE PAPERS BY MR. LEDWARD (SEE PAGE 113) AND MR. SHOTTER (SEE PAGE 128).

Dr. E. Hughes: I shall confine my remarks to Mr. Ledward's paper.

About three years ago I spent a good deal of time trying to explain the asymmetric *E–I* curves referred to in the paper. At first, I was concerned with proving the genuineness of the phenomenon, and trying to show that it was not merely a direct current in the oscillograph which was causing the polarization. I was, however, unable to arrive at an explanation and thought it best to publish the information and to let someone else investigate the problem.

The superposition of direct current to produce polarization, as described by the author, is a very effective way of proving a difference between the polarization due to direct current and that which remains after exciting with alternating current. What I regard as one of his most important discoveries is the fact that a very thin sheet of nickel-iron, only 0·015 in. wide, can be polarized in two different directions simultaneously.

I should like to emphasize the great difficulty experienced in eliminating all traces of polarization. However much care is taken, there is always a slight trace of polarization left, and the author's experiments are very interesting in showing how harmonics may result from the presence of a very small initial polarization.

In connection with the question of the sub-harmonics and even harmonics, the author mentioned that he had found a sub-harmonic to occur only with the iron-nickel alloy. About 10–12 years ago I chanced to come across that phenomenon with charcoal iron, but was unable to pursue the subject further at that time. Recently, however, Prof. Goodlet "observed both even and sub-harmonics, the occurrence of which it is hoped to explain at some future date."* I think that the present author has explained very satisfactorily the fact that these even harmonics and sub-harmonics are really due to resonances which take place with appropriate capacitances and the inductance of the coil. He used a 1-μF condenser for the sub-harmonic, whereas he had only 0·1 μF for the 2nd harmonic (100 cycles per sec.): allowing for a slight change in the inductance of the coil, this will easily account for the 4 : 1 ratio of the frequency.

One important point about the paper is that it shows how difficult it is to ascertain the conditions which obtain with any magnetic circuit of this type; and therefore how necessary it is to have some means of checking the conditions, especially in view of the fact that the asymmetric is far more stable than the symmetrical condition.

(*Communicated*) In his contribution to the discussion, Mr. Ockenden drew attention to the desirability of maintaining sinusoidal the flux density and not the magnetizing force, and stated that it was only necessary to adjust the induced e.m.f. to be sinusoidal in order that the flux density should have the same wave-form. This relationship is practically correct for materials such as stalloy but does not hold for high-permeability nickel-iron alloys. It was shown in my paper† that the flux density at the centre of a mumetal lamination may be only about 6 % of that at the surface and that the two flux densities may be approximately in phase opposition. Consequently, a sinusoidal induced e.m.f. would merely mean that the *average* flux density over the whole section was sinusoidal; but the flux density at any particular depth could depart very considerably from that wave-shape, and the results would be even more indefinite than with a sinusoidal current.

Dr. W. G. Radley: Mr. Ledward states that many of the phenomena described should be taken into account in the design and operation of transformers and chokes, particularly when used in measuring instruments and in telecommunication apparatus. It is well known that the use of telecommunication apparatus including magnetic material introduces a distortion, owing to the non-linear relationship between magnetizing force and flux. In modern carrier communication circuits incorporating transformers and filter coils this causes intermodulation between channels employing different carrier frequencies. Experience has shown that the trouble is not so serious in the case of transformers which are bridged across the line as it is in the case of filter coils in series with the line. This is probably owing to the higher magnetizing forces in the latter case. A study of these effects has led the Post Office to attribute all the intermodulation to 3rd-harmonic components; the presence of the asymmetric effects due to even harmonics which the author describes has never been suspected. The probable reasons are: firstly, the magnetic loading of a transformer designed for a telephone circuit is very much less than the values for which the author's asymmetric loops were obtained; 0·1 ampere-turn per cm. is about the maximum magnetizing force associated with stalloy cores, whereas with mumetal cores the maximum is about 0·03 ampere-turn per cm. Comparing these values with those relating to some of the loops shown in the paper, one finds that with such magnetizing forces the loop is becoming symmetrical. The residual magnetization which gives the asymmetry was, it is gathered, produced by the application of very much higher magnetizing forces. Secondly, the frequencies concerned in telecommunication circuits are much higher than those dealt with by the author, and the asymmetrical effects become less as the frequency increases. Lastly, of course, there is the point which is mentioned in the author's conclusion, that ring stampings are very rarely used in modern apparatus. With E- or U-shaped stampings the effects begin to disappear.

Mr. J. Greig: It is interesting to note Mr. Ledward's experience with silicon steels. The experience of Dr. L. G. A. Sims and myself, extending over several years and involving many hundreds of measurements on materials of this class subjected to combined a.c. and d.c. polarization, tends to confirm Mr. Ledward's results. It is found that good repeat accuracy occurs with any given nominal excitation condition, even if the normal demagnetization procedure prior to test is omitted. In a particular series of repeat measurements made to test this point, it was found that the delicate balance of an a.c. potentiometer was scarcely disturbed, even though appreciable liberties were taken with the excitation between successive tests.

* *Journal I.E.E.*, 1934, vol. 74, p. 379. † *Ibid.*, 1936, vol. 79, p. 213.

One notes with interest that Mr. Ledward used a synchronous rectifier for the tests described in Section (10) of his paper. Our experience with synchronous rectifiers has not been a happy one, but as Mr. Ledward was looking for small differences he has presumably secured satisfactory operation from his rectifier. I should be glad if he would comment on this matter and give some information as to the means he adopted to secure satisfactory operation to close limits.

Mr. F. E. J. Ockenden: Towards the end of Section (4) of his paper Mr. Ledward says: "It was found generally that if the primary current was broken at any given value, the residual polarization as indicated by the ballistic-galvanometer deflection on breaking could be removed by applying the same current again." Does this mean that the current has to be re-applied at the point in the cycle at which it was broken off?

At the beginning of Section (6) the author says: "The asymmetry should be obliterated if direct current of suitable value and sign is continuously applied." I gather that this applies when the material within the ring is shielded by eddy-current effects occurring on the surface, so that under a.c. conditions demagnetizing effects do not reach the centre of the ring. If this is the case, surely the more straightforward procedure would be gradually to reduce the frequency to zero (since obviously at zero frequency there would be no eddy-current protection), checking the successive wave-forms. The author mentions that he raised the frequency for other purposes, but does not say whether he tried frequencies below 50 cycles per sec.

He omits to mention that the maximum flux and the $(IT)_m$ value of the magnetizing current are not strictly in phase, owing to the presence of eddy currents. We therefore do not know to what extent the deviations shown in Fig. 22 are due to the causes which he suggests or merely to idiosyncracies of wave-form which have affected the phase relationship between the peak of the magnetizing current and the peak of the flux. Fig. 21 shows that the author uses a sinusoidal magnetizing current and a non-sinusoidal flux containing many harmonics. The eddy currents introduced in the surface of the ring being tested will be dependent on the frequency of the flux producing them, and therefore on the harmonics in the wave-form. I have long felt that this method of passing a sinusoidal magnetizing current through a ring and accepting any flux wave-shape which happens to arise is unsatisfactory. My method is to use a ring having two windings T_1 and T_2 closely interwound, each with the same number of turns, and connected non-inductively one to the other as shown in Fig. A. The current through the coils is controlled by the variable resistor R_1 and the magnitude of the flux by the resistor R_2. Under these conditions the flux is maintained closely sinusoidal and its value is determined by the e.m.f. across the search coil T_s. The non-sinusoidal magnetizing current traverses the low-resistance shunt S_2, and by means of a suitable amplifier an oscillographic record of the current and the induced secondary voltage may be obtained from the coil T_s and the drop across the shunt S_2 respectively. The phase relationship between the fundamentals of these two quantities may also be checked by comparing the e.m.f. across S_2 and that across S_1. By the use of such a circuit in place of that shown in Fig. 21, investigations into the effects discussed by the author could be carried out without the complications involved when the flux wave departs seriously from the sine wave-form.

Turning to Mr. Shotter's paper, in Table 1 the author shows a burden of 1 VA on the 5/5 range and 4 VA on the 2·5/5 range, which is just what it should be if nothing extra is allowed for the resistance of the transformer windings. On the other hand, at the 1·25/5 range the volt-amperes suddenly go up to 25, which means an allowance of 9 VA for the transformer itself. It is of course possible that the transformer winding had an extraordinarily large leakage reactance, and this may well be the cause of the negative phase-angles recorded in Table 6.

The author introduces condensers for compensating his transformers; a 75-μF condenser is very unwieldy, unless of the electrolytic type or one made for a very low operating voltage, in which case the permanence of the overall accuracy might be open to doubt. The difficulty could be got over more simply, I think, by adding a tertiary winding. In most cases this would not be a matter of

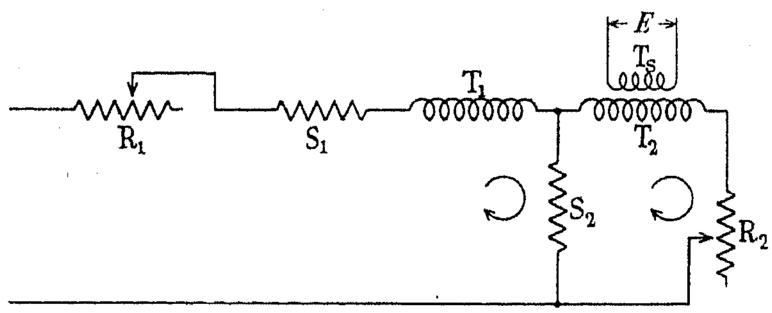


Fig. A

any great expense. The winding can be as fine as is desired; it only has to carry the neutralizing magnetizing current. The advantages of a tertiary winding are that it reduces the value of the condenser required from 75 μF to any desired value, depending on the number of tertiary turns chosen; and also, since the condenser is energized by the whole of the e.m.f. induced by the flux in the core and not merely by the potential across the secondary terminals, the compensation tends to follow more closely the normal regulation of the transformer than does the common scheme of putting it across the secondary terminals. The resistance method of compensation referred to in the paper is quite useless except for burdens of very low power-factor.

The use of auxiliary transformers is likely to be reasonably satisfactory when applied to transformers having a phase displacement of 10 minutes or more; but it is sometimes asked whether such auxiliary transformers can be used with precision transformers where the phase displacement is only 0·2 to 0·4 minute, in order to change the secondary range from 5 amperes to 1 ampere. The total burden due to such an auxiliary transformer would be 40 or 50 VA, and the effect on the performance of the main transformer would be disastrous.

Mr. J. G. Wellings: I should like to emphasize that the final useful burden on the combination of current-transformer and auxiliary current-transformer, mentioned

in Mr. Shotter's paper, is very small—only 0·8 VA. The main current-transformers which the author used are very good ones, and it is subject to those main current-transformers being accurate down to very small primary currents, and to the secondary burden being kept small, that the whole scheme is successful. Theoretically, of course, there is no difference between this scheme and tapping the main current-transformer direct, without an auxiliary current-transformer. I agree with the author that there are certain difficulties in tapping the secondary windings on current transformers; undoubtedly the lower the tapping the greater the difficulty, because not only does the precise number of turns cause trouble (sometimes involving fractional turns) but also the disposition of the turns on the core becomes very important. The turns must be evenly distributed around the core or there will be appreciable secondary reactance and the accuracy of the transformer will be impaired, apart from the effect of the reduced number of ampere-turns with a tapped winding. The advantages of the method are that it permits the use of a main current-transformer which is without tappings, and this tends towards standardization; and also that the auxiliary units can easily be standardized. The method also eases the situation as regards the short-circuit rating of the main current-transformer. Normally a low-ratio transformer has to be used for metering small currents, and there is difficulty in making such a transformer stand up to the short-circuit current of the system. Transformers can now be made with very much higher overcurrent factors, as now termed in the new British Standard Specification, but that tends again towards special construction, whereas with the author's scheme it is possible to use quite a standard type of current transformer with a high ratio, so that it is capable of withstanding the short-circuit current of the system.

I should like to ask the author whether he has considered the use of a ring core instead of a shell-type core for the auxiliary current-transformers, because our experience is that a transformer with a shell-type core gives extra magnetizing current by reason of the joints in the core, and it also has higher primary and secondary reactance. The design of these auxiliary transformers is rather special in that it is necessary to consider the primary resistance and reactance as well as the secondary resistance and reactance, because both the primary and the secondary load back on to the main current-transformer.

I should like the author to confirm that the volt-ampere values quoted in Tables 1 and 2 all refer to a 5-ampere basis. In Table 3, a mysterious 6 VA creeps into the values of the secondary burden in Tests C, D, and E, and I should like to know what this figure of 6 VA represents.

I am interested to note the difference in the results obtained with the two types of auxiliary transformers, referred to as "No. 5" and "RB." I gather that Type RB was used for the tests recorded in Tables 3, 4, 5, etc., but this is not quite clear. I am also puzzled about why the phase-angle errors quoted in Table 3, cols. A and C, are of negative sign; it seems to me that they ought to be positive.

The author refers to the transformer as having a "hybrid core"; does he mean that the core is made of a combination of mumetal and stalloy?

Capt. B. S. Cohen: Mr. Wellings referred to the expression "hybrid core": I hope that Mr. Shotter will substitute another term, because there is a well-known piece of apparatus used by communication engineers which is often referred to as a hybrid transformer.

Mr. J. W. Carter: I can appreciate Mr. Shotter's remarks regarding the difficulty of always obtaining adequate loading of meter equipment and the impracticability of changing current-transformers to meet conditions which are often temporary; this is especially the case with supplies taken directly from the high-voltage system with metering on the high-voltage side of the consumer's transformers. With such metering the circumstances are difficult for the designer of current transformers, for he must in the first place provide for an adequate overcurrent factor, and secondly maintain high accuracy. With full-load primary currents as low as 10 amperes there often has to be a sacrifice of burden capacity in order to meet these requirements, and this is not favourable to the use of auxiliary current-transformers. A partial solution of this difficulty might be obtained by using a 2·5-ampere long-range meter in conjunction with the ordinary transformer of 5-ampere secondary, providing a transformer can be made with a range comparable with that of the long-range meter. By this means an increase of 100 % in range could be obtained without the disadvantages of altering connections or using dial constants.

Mr. T. A. Ledward (*in reply*): Explanations were put forward in the paper to account for many of the phenomena described, and I am interested, but a little disappointed, to find that no one has challenged or added anything to my own theories. As Dr. Hughes has remarked, some of the phenomena have been observed before but in most cases have not been explained.

Dr. Hughes's remarks as to the effect of using a sinusoidal induced e.m.f. in the case of mumetal are very interesting and show clearly that the usual assumption that this will result in a sinusoidal flux throughout the stamping may be quite incorrect.

Dr. Radley states that the asymmetric effects described do not appear to be seriously in evidence in telecommunication work, owing to the different conditions obtaining in this work as compared with the conditions of my tests. My intention in stating that these phenomena should be taken into account in telecommunication work was to indicate that unsuspected effects might arise if certain conditions obtained, although in present-day practice such conditions may not usually be present. I had in mind particularly the fact that in telecommunication work iron cores may, in some instances, be used with windings connected directly in the anode circuits of thermionic valves, the cores being thus polarized.

Mr. Greig states that he has had some difficulty in securing satisfactory results with synchronous rectifiers, but he does not mention the nature of the trouble experienced. My rectifier was of small diameter—about $\frac{3}{8}$ in.—and the segments were of pure silver. The contact brushes also were of pure silver wire. I have found that copper or brass is useless for accurate work. The brush position was adjusted carefully to give a maximum

deflection for each reading, as the phase angle between the supply voltage of the driving motor and the voltage to be rectified may vary with different values of excitation of the test sample. It is interesting to note that this phase angle varied greatly with mumetal specimens, but only to a very small extent with stalloy. It was found necessary to earth the framework of the driving motor and to twist together the leads both to the rectifier and to the galvanometer, as the apparatus was very sensitive to a very small amount of leakage or induction.

In reply to Mr. Ockenden's query regarding Section (4), the residual polarization was removed by applying the same r.m.s. value of current again. It was not necessary to re-apply the current at any particular point in the cycle.

Mr. Ockenden suggests that the frequency should be gradually reduced to zero and the successive wave-forms checked. This would certainly be an interesting test and should furnish some useful data, but there are difficulties in arranging suitable apparatus for reducing the frequency gradually to zero while maintaining $(IT)_m$ constant and also maintaining a good wave-form. The results of such a test would, however, be very interesting, although the specimen would not, of course, be demagnetized. If the magnetizing current were gradually reduced to zero at the same time as the frequency, the test would be simple to arrange and the specimen would probably be demagnetized, but it would not be possible to obtain much useful information at the successive frequencies.

Mr. Ockenden's method of obtaining a sinusoidal flux is interesting, but, as pointed out by Dr. Hughes, it would not give any more definite results in the case of these particular tests of nickel-iron alloys than are obtained by the use of a sinusoidal magnetizing current.

[**Mr. Shotter's** reply will be published later.]

DISCUSSION ON

"A STATISTICAL EXAMINATION OF SPECIFICATIONS FOR THE MECHANICAL TESTING OF LINE INSULATORS"*

Mr. F. R. Perry (Nigeria) (*communicated*): The author has, I believe, performed a valuable service in applying statistical methods of analysis to the specifications dealing with the mechanical testing of insulators. Any testing specification is, after all, a compromise between the impossible ideal of testing every insulator unit which is to be used in service and the equally unsatisfactory method of accepting all units on trust, i.e. accepting the qualities of the insulator as detailed in the manufacturer's catalogue without any form of test. While testing specifications are drawn up with great care, with the object of performing the required tests on a "representative" sample of the insulators being purchased, it is useful to examine, as the author has done, exactly what are the limitations of the sampling methods proposed and to what extent the samples tested can be relied upon to give an accurate picture of the qualities of the batch of insulators as a whole. He clearly establishes that, under certain unfavourable circumstances, the existing specifications may permit of conditions in which a string of 9 suspension units may contain 2 units which would not have passed the mechanical tests, had they been subjected to them. Whether this would really be a dangerous condition or not would depend on the amount by which the defective units failed to reach the desired standard, and under the sampling conditions as at present specified there is no means of estimating how large this discrepancy might be. In view of this possible condition, it would be of interest to know whether any mechanical failure of suspension insulators has occurred on grid lines, and, if so, whether it has been possible to explain them except as freak failures such as the author shows might be possible owing to limitations in the sampling method.

The author confines his analysis to insulator strings composed of 9 units, although in Appendix 3 he briefly considers the case of a double tension-string of insulators. I assume that he again postulates a string of 9 units, making 18 units in all in the double string. As, unfortunately, I am not in a position to consult the testing specifications to which the author refers, I cannot verify whether the following observations are correct. Speaking from memory, however, it is my impression that where tension strings, as opposed to suspension strings, are used on the 132-kV lines of the grid, more than 9 units are used per string. In fact, 10 or 11 units may be employed under certain conditions, and, where atmospheric pollution is severe, as many as 12 units may constitute a string. It is possible that the testing specifications take cognizance of this fact and impose special means of sampling. If not, it occurs to me that the probability of a string of 10 or 11 units containing more than two mechanically-weak insulators might be enhanced, and although only one defective insulator in a string would be sufficient to cause failure, yet if the string contained, say, 3 units which fell below the required minimum mechanical strength, the possibility of one of these units being defective would be increased. It would be of interest if the author would indicate briefly whether such would be the case. This point may be of importance, as insulators used in tension strings will, in general, be subjected to a higher working mechanical stress than insulators used in suspension strings.

As part of the author's argument is based on the assumption that if a batch of insulators were tested to mechanical destruction the distribution of results would obey some form of the normal-frequency law, giving the type of curve shown in Fig. 3, it would be desirable to obtain experimental verification of this point. This would not be difficult if porcelain manufacturers would agree to supply the material on which an independent testing laboratory could carry out the necessary mechanical tests. If two or three of the leading makers were to supply batches of insulators for test and if batches made by different firms all showed an adherence to the normal-frequency type of distribution of results, the author's assumption would be proved correct and his analytical treatment justified. In view of his remarks about the tendency to improve the mechanical strength at the expense of the resistance to thermal changes, it would appear that a series of tests to destruction by means of the temperature-cycle test would also be of value. I am not aware that many insulators of modern manufacture fail during a temperature-cycle test in which the insulator is plunged into hot and cold baths alternately, of 100° and 0° C. respectively. It would be of interest to know, however, what factor of safety an insulator passing such a test might have, and this could be determined by raising the temperature of the hot bath (using heated oil, for example) and by retaining the cold bath at the usual temperature of 0° C. By gradually raising the hot-bath temperature it should be possible to reach a stage where the insulator was destroyed, and by repeating the test on a number of insulators of the same type the law of the distribution of results with respect to the hot-bath temperature, or with respect to the temperature-difference between the two baths, could be obtained. Such a test would be very tedious to perform, but it would show the margin of safety between a test to destruction and the normal temperature-cycle test which the insulator is expected to withstand without harm.

It is true, as the author points out, that the temperature-changes which an insulator may undergo during thunderstorm conditions are very severe, though probably not so drastic as he would appear to indicate. For example, taking the figures quoted in the paper,

* Paper by Mr. W. T. O'Dea (see vol. 83, p. 333).

there need not necessarily be a sudden change from the sun temperature of 130° down to 32° F. From my observations of lightning storms in South Africa and Nigeria, I would say that the usual sequence of events when a thunderstorm arrives is that the clouds generally obscure the sun for at least a few minutes before any rain or hail is discharged from the cloud. Hence the hottest portion of the insulator, i.e. the side formerly in the sun, will tend to cool slowly down to the shade temperature before it is rapidly cooled by falling rain or hail. Moreover, when hail is discharged from a thundercloud it frequently happens that rain has been discharged some little time before, and although the temperature of this rain is low it will not necessarily be as low as 32° F. While, therefore, the temperature-changes are severe, it is unlikely that the complete change from sun temperature to freezing point will take place in one rapid stage. Nevertheless, it is true that power companies operating in countries where lightning storms are frequent have had a great amount of trouble due to cracked insulators. One company of which I have knowledge, operating in South Africa in a region where severe lightning storms are of almost daily occurrence during the wet season of 5–6 months' duration per year, had many hundreds of pin-type insulators which developed cracks after some years' service and in consequence had to be replaced. It is possible that these insulators were manufactured before the time when steam-curing of the cement was adopted to prevent its ageing and expanding during service. The cracking of the porcelain may therefore have been due to cement expansion rather than to the severe thermal stresses set up by temperature-changes. On the other hand, this same power company has recently experienced trouble of a similar nature, i.e. cracking of the porcelain, with suspension-type insulators of modern make. This is rather alarming, seeing that a suspension insulator is a much less complicated structure than a multi-shed pin-type insulator. Whether the failure of these suspension insulators was due to thermal stresses, to ageing of the cement, to insufficient mechanical strength, or to a combination of all three causes, it is clear that a revision of the testing specifications, as advocated by the author, would be beneficial. It is not known, in the above instance, what form of testing specification was used in the contract, but the author's contention that a proper balance must be maintained between the rival claims of high mechanical strength, high heat resistance, and high puncture value, should be noted both by manufacturers and by those responsible for drawing up testing specifications.

Mr. W. T. O'Dea (*in reply*): Fig. 9, as Mr. Perry points out, applies to double 9-unit strings only. Where longer strings are employed the position becomes relatively more serious. More important than the production of exact numerical figures is the demonstration of the fact that the "guaranteed minimum" may not be guaranteed from sample test-results of the kind under consideration. It therefore seems regrettable that manufacturers should find in the "guaranteed minimum" an encouragement to neglect factors other than mechanical strength. The specification analysed in the paper, for instance, caused one firm to abandon a porcelain body developed by generations of good potters, in favour of a "hard paste," which was grudgingly admitted to have a better chance of test acceptance. Mr. Perry is correct in his supposition that an increase in the average number of "defectives" per string implies a greater probability of the degree of defectiveness of at least one unit being more serious.

His suggestions with regard to the possibility of initiating tests to establish the worth of certain parts of the paper are interesting and welcome. It would be necessary, as far as the frequency-distribution tests are concerned, to ensure that the submitted batches had been statistically controlled during production. It may not be inappropriate to mention that the analysis of Figs. 1 and 2 is not affected by whatever results may be obtained from such tests.

With regard to temperature-cycle tests, the present limits have clearly been dictated by the convenience with which the temperatures of (*a*) boiling water and (*b*) ice and water may be standardized. The upper limit, however, might easily be raised by making use of the fact that the boiling point of an aqueous solution rises by a specific amount per mol per litre of dissolved salt. This should be an improvement on heating a large bath of oil. The tests suggested by Mr. Perry might be very valuable in spite of their tedium, and they might be amplified to include the effect of various cycles repeated until failure occurs. Incidentally, it seems desirable that the testing baths should be standardized.

The practical experiences of excessive service losses recounted by Mr. Perry are most interesting and may tend to substantiate the conjectures made in Section (6) of the paper. Loss due to expansion of cement should not occur in properly designed insulators, particularly those of more recent date. Even steam-curing should be unnecessary and ineffective if assembly has been carried out with small batches of fresh, fully hydrated sand/cement mixture using portland cement. One or more characteristics such as (i) faulty design, (ii) faulty assembly, or (iii) poor porcelain body, must have been responsible for the failures. Faulty design is sometimes due to a customer's prejudices being stronger than his knowledge of potting, but the manufacturer cannot offer excuses for defects (ii) and (iii). A more severe thermal test, however, should in many cases detect their presence.

Mr. Perry's first-hand observations of thunderstorm conditions are very welcome, and I am pleased to see that, even if he does not entirely endorse my suppositions, he still regards possible thermal stresses as severe. Making allowance for the probable obscuration of the sun for a few minutes before the rain or hail comes, it is still likely that severe complex skin and internal stresses may be experienced, as porcelain does not very rapidly conduct away its heat to the air. It is, in fact, possible that troubles due to thermal stresses may be cumulative in certain respects. Some years ago tests were taken on a number of cementless Hewlett insulators to discover the effects of prolonged freezing and thawing with the top U-shaped link hole filled with water. The results over many cycles were negative, but units of the same kind had a fairly short and chequered career in a situation where freezing was not uncommon. I should not be surprised to hear that the insulator units which failed so badly in Africa were satisfactory for a year or two.

I should like to endorse strongly Mr. Perry's concluding remarks and to add that there still remains a very wide field for investigation of the more ordinary aspects of insulator behaviour. I should expect valuable and rapid results to follow a greater degree of co-operation between manufacturers, customers, and those whose task it is to draw up specifications.

THE MAGNETRON*

By J. E. HOULDIN, B.Eng., Student.

[ABSTRACT *of Paper read before the* MERSEY AND NORTH WALES (LIVERPOOL) STUDENTS' SECTION *16th February*, 1937.]

INTRODUCTION

Short-distance radio communication, including television, has demanded an increasing technical interest in those wavelengths below 10 m. Subsequent development in technique has widened the field of the practical applications of these wavelengths to include their use in radio beacons, especially for aircraft, therapeutic research in medicine, and physical research in the study of dielectrics.

A triode oscillator can be designed to operate at these high frequencies, but there is a tendency for it to be replaced by the magnetron oscillator owing to the latter's higher efficiency and output under similar conditions.

CONSTRUCTION

In the simplest type of magnetron the electrode system, contained in a vacuum tube, is essentially that of a diode (see Fig. 1). A tungsten filament, stretched between two

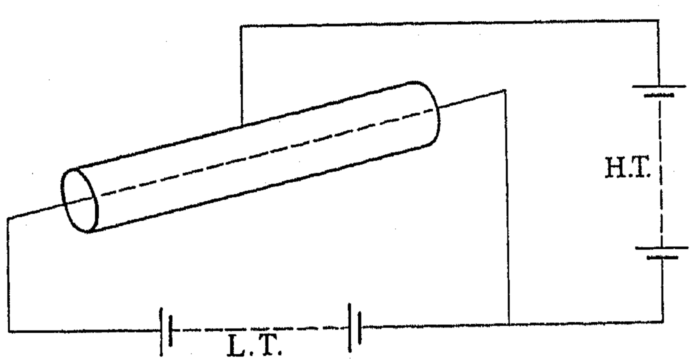


Fig. 1

supports, is connected to a filament supply. A cylindrical anode, concentric with the filament, has a high positive potential, referred to the filament, applied to it. The current which flows from the anode to the filament will be limited by either the filament temperature or the anode potential.

OPERATION

A magnetic field is applied to the electrode system, its axes approximately coincident with the filament. The anode current is unaffected by magnetic fields weaker than a certain critical value, but with fields above this value the anode current is reduced practically to zero (see Fig. 2).

A simple explanation of the effect of the magnetic field is represented in Fig. 3. The field imparts to electrons travelling towards the anode a radial velocity which, when the field has a certain critical value, will be sufficient to cause the electrons to miss the anode and return to the filament. At this point the anode current will be reduced from its initial value to zero. The cut-off in practice is

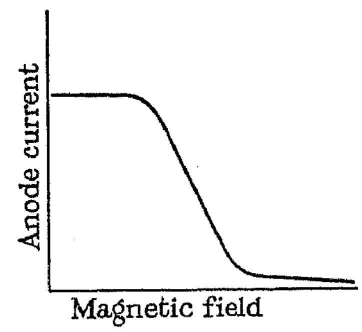


Fig. 2

not so sharp, owing to lack of symmetry in the electrode layout, the filament not being at uniform potential throughout, the electrons having different velocities of emission and some of the electrons being emitted in directions other than normal to the filament.

EARLIER WORK

As far back as 1921, A. W. Hull introduced this new member of the vacuum-valve family, described its construction, and outlined possible applications of the valve. Comparatively low-frequency oscillations were obtained by means of these valves by Hull and Elder before 1925.

In 1923, A. W. Hull described a new type of magnetron valve which required no external magnetic field and could be used for high-power conversion from direct current to

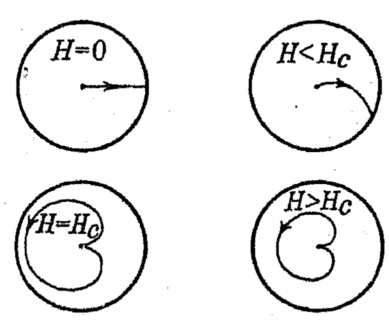


Fig. 3

alternating current. A large current was passed through the filament of the valve, and the magnetic field of the current was sufficient to cause the electrons to miss the anode and return to the filament (see Fig. 4).

* The original paper, of which this is an abstract, was awarded a Students' Premium by the Council.

Using a pair of valves, with a maximum filament current of 4 400 amperes, and a direct anode voltage of 100 000 volts, it was possible to obtain an output of 10 000 kW of alternating current at an efficiency of 96 %.

METHODS OF OSCILLATION

At the present time the most extensive use of the magnetron valve is for the production of very high frequencies.

In the original design of magnetron valve a single cylindrical anode was used. The use of this valve necessitated unsymmetrical circuit arrangements, which are inadvisable in connection with high-frequency oscillations; so that, for the latter, the split-anode magnetron valve was evolved. The electrode arrangement of this is exactly similar to that of the single-anode valve except

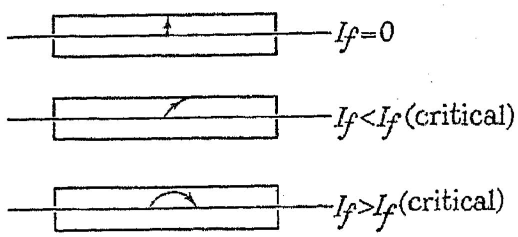


Fig. 4

that the anode is made in two halves, insulated internally from each other and connected externally by the tuned circuit. The anode H.T. supply is taken to the mid-point of the tuned-circuit inductance.

(a) Electronic Oscillations

Both types of valves are found to oscillate at very high frequencies, corresponding to wavelengths of 1–5 m., and at these frequencies the time of transit of electrons from the cathode to the anode is comparable with the period of oscillation. These oscillations are generally known as " electronic," and of the many theories advanced to explain the method of generation perhaps the most successful is that of Megaw, which was published in 1936.

The electrons travel in spirals towards the anode, and on each close approach to the anode give high-frequency energy to the tuned circuit. If it could be arranged that the electron struck the anode when its energy and spiral amplitude were least, then maximum high-frequency output would be obtained from the valve. There are two methods of obtaining these conditions: (i) by tilting the magnetic field at an angle to the filament, and (ii) by the use of end-plates maintained at a positive potential.

The tilting of the magnetic field has the effect of giving the electron a helical path whose axis is that of the magnetic field. With an inclination of 7°–10° of the magnetic field the electrons reach the anode when their spiral amplitudes and energies are a minimum. The output of the valve is then a maximum.

An axial electric field superimposed on the anode radial field gives the electrons an axial component of velocity which has the effect of moving the electrons in a helix whose axis is inclined to the filament. If the axial field is set at the correct value the electrons will reach the anode at a time when they possess least energy. The output is then a maximum. The axial field is produced by two plates perpendicular to the filament and arranged at each end of the anode segments. To each of the plates is applied a positive potential equal to about $\frac{1}{2}$–$\frac{3}{4}$ of the anode potential.

(b) Dynatron Oscillations

The split-anode magnetron valve will oscillate from 50 cm. wavelength down to audio frequencies, but above 8 m. wavelength the method of oscillation is different from that of the electronic oscillator. The frequency no longer depends on the rotational frequency of the electrons but depends on the natural frequency of the tuned circuit connected between the anode segments. This type of oscillation is termed " dynatron," and is unique to the multi-segment magnetron valve.

The transition point at which the type of oscillation changes is not definite, and in all probability between the wavelenths of 2 m. and 8 m. the oscillation is a mixture of electronic and dynatron. It is in this range that the efficiency of the magnetron valve reaches its maximum.

The dynatron oscillation effect is due to the negative-resistance characteristic of the valve when the applied magnetic field is greater than the critical value. If this negative resistance is greater than the positive resistance due to the losses in the tuned circuit, then the latter can be made to oscillate continuously.

CONCLUSION

The study of the magnetron as an amplifier has not been taken up as yet, but its future as detector and oscillator is assured, especially where large powers at very high frequencies have to be handled.

THE OIL CIRCUIT-BREAKER*

By J. W. FAIR, Graduate.

[ABSTRACT *of Paper read be ore the* MERSEY AND NORTH WALES (LIVERPOOL) STUDENTS' SECTION 16*th March*, 1937.]

CIRCUIT-BREAKER PROBLEMS

In view of its importance in modern electric power schemes, the circuit-breaker must be capable of performing its maximum rated duty with perfect reliability at all times. Experience with early air-break switches proved the value of immersion of contacts in an insulating liquid. The switch oil used for this purpose has valuable properties as a cooling, restricting, and insulating medium for power arcs, and enables the fire risk to be conveniently minimized. Although some countries use oil-less switches, Great Britain and the U.S.A. prefer the modernized oil circuit-breaker.

The double-break type, in which the contact assembly and operating mechanism are carried on a top plate, with the oil tank bolted beneath, has been the standard design in this country for many years. Early designs were not sufficiently robust, and had weaknesses which only experience under actual fault conditions could expose; these are, briefly: (*a*) Sustained arcing produces gas and oil-vapour very rapidly, causing large tank pressures. (This gives rise to burst tanks, distorted top-plates, and delayed contact travel.) (*b*) High tank pressures cause hot oil and gas to be driven out from the enclosure, often starting oil fires. (*c*) Arcing contacts may be destroyed, and main contacts damaged, by powerful arcs. (*d*) Large electromagnetic forces, encountered during faults, distort the contact supports, and produce dangerous "kick-off" forces should the switch be closed on a fault.

Later designs, which have given years of satisfactory service, overcame these troubles by modifications dictated by experience. (*a*) is corrected by using strong, tested tanks, cylindrical if possible, together with reinforced top-plates, and further reduced by employing non-reciprocating types of mechanism. (*b*) is minimized by a correctly proportioned air-cushion and head of oil above the contacts, and by accurately fitted joints with baffled release-vents. The use of heavy arcing contacts with a large lead over the main contacts reduces (*c*) to small proportions, whilst (*d*) is overcome by employing solid conductors with bakelized-paper insulators wherever possible. To a\ oid the danger of "kick-off" forces, hand-closing is used only on smaller sizes of gear, with improved mechanisms; large breakers are operated by powerful mechanical closing devices.

SWITCHGEAR TESTING STATIONS

To rely entirely on actual operating experience for design data is obviously unsatisfactory, and, in spite of the heavy costs, the necessity for large-scale controlled testing has led to the establishment of various switchgear-testing plants. The first British station was built at Hebburn-on-Tyne in 1929.

Testing power in such plants is derived from a generator which has a very heavy rotor, and specially-braced windings; this machine is brought up to full speed by a motor, and the stator is then connected across the switch under test, via any necessary resistors and reactors. The largest output yet obtained from a single machine is about 1 500 000 kVA at 0·1 power factor.

The definite circuit-breaker performance guarantees obtained from test-plants have helped to remove much uncertainty, and have considerably strengthened confidence amongst users.

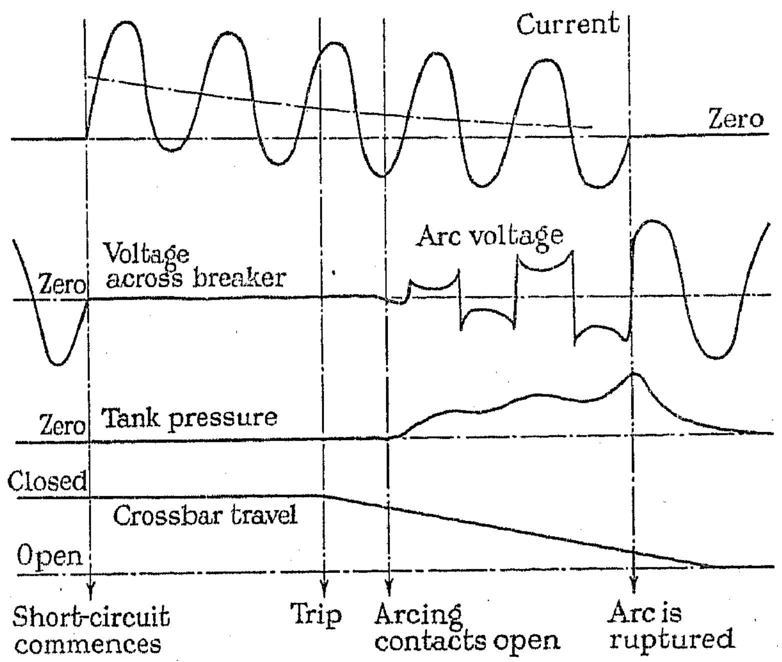


Fig. 1.—Oscillogram of test on an oil circuit-breaker (one phase only).

RESEARCH IN CIRCUIT-BREAKING UNDER OIL

Complete knowledge of the phenomena of arcing is not yet available, since such research is difficult to carry out, but a considerable amount of successful work has been accomplished.

As is indicated by the test oscillogram shown in Fig. 1, the arc is formed as the arcing contacts part after the switch has been tripped. The crossbar travel proceeds, and the arc voltage and the tank pressure increase steadily, showing the necessity for rapid extinction to avoid large stresses.

At each current-zero the arc ceases momentarily, and the problem is, obviously, to prevent restriking; the arcing contacts are surrounded by an atmosphere of extremely hot, highly ionized gas, and the voltage is building up across them. If the rate of rise of this

* The original paper, of which this is an abstract, was awarded a Students' Premium by the Council.

restriking voltage is rapid, the gas will break down again, and the arc will restart for a further half-cycle. This will continue until a zero point is reached at which the gas bubble will be sufficiently cooled and de-ionized to prevent restriking.

This imperfect de-ionizing process results in the development of a large amount of arc energy and stress on the switch, and a means for controlling the gas bubble and arc path would reduce this considerably. Various methods of control are now available: for an oil switch the most promising is complete removal of the ionized gas, and replacing it by cool, non-conducting oil vapour, which will effectually prevent restriking.

Modern oil circuit-breakers fitted with arc-control devices give rapid and certain interruption up to their full rated capacity, without undergoing heavy stresses. Two general principles are employed: (*a*) The energy for the removal of the ionized gas may be obtained from the arc itself, as in the Cross-jet Pot; or (*b*) this energy may be derived from a spring-loaded plunger, as in the Oil Pressure breaker. The efficient action of such devices has enabled the single-break switch, with its several advantages, to be re-introduced.

CONCLUSION

Although sufficient is now known for it to be possible to produce reliable breakers for normal duties, several important problems still remain. Amongst these are the necessity for a fuller understanding of restriking phenomena, and the lack of an internationally agreed method of calculating circuit-breaker performance. However, the rapidity of recent progress gives hope of an early solution to such problems, and shows that development is at least keeping pace with that in other items of plant.

PROCEEDINGS OF THE INSTITUTION

934TH ORDINARY MEETING, 20TH OCTOBER, 1938

Sir George Lee, O.B.E., M.C., the retiring President, took the chair at 6 p.m.

The minutes of the Annual General Meeting held on the 12th May, 1938, and of the Ordinary Meeting held on the same day, were taken as read and were confirmed and signed.

A list of candidates for election and transfer, approved by the Council for ballot, was taken as read and was ordered to be suspended in the Hall.

The Chairman announced that during the period May to September 698 donations and subscriptions to the Benevolent Fund had been received, amounting to £759. A vote of thanks was accorded to the donors.

The Premiums (see vol. 82, page 698, and vol. 83, page 288) awarded for papers during the past session were presented by the Chairman to such of the recipients as were present.

Sir George Lee then vacated the chair, which was taken by the new President, **Dr. A. P. M. Fleming, C.B.E., M.Sc.**

Mr. Ll. B. Atkinson: In the unavoidable absence of one of our recent Past-Presidents, Mr. J. M. Kennedy, I have been asked at short notice to put before you the following resolution: "That the best thanks of The Institution be accorded to Sir George Lee for the very able manner in which he has fulfilled the office of President during the past year." The words of this resolution are, of course, formal, following long-established precedent; but in proposing the resolution, and in our intention, there are no thoughts of formality, but only of sincere regard for him. We have had several Presidents in the past who occupied, as Sir George does, the position of chief engineer of the Post Office. I will refer to two who have affected my own life. First there was the late Sir William Preece, who, anxious as he always was to help the younger members of the profession and of this Institution, took a great part in placing me in the electrical industry. And the second is Sir Thomas Purves, who, in replacing me in the duties I had performed for many years, helped me to retire from the electrical industry. Sir George Lee's term of office has not been marked by any startling events in our Institution, but by the latter's steady progress, in which he has taken an active part. I will only mention one or two special items. In his Presidential Address he referred to the desirability of co-ordinating as far as possible our activities with those of the other great engineering Institutions on matters of common interest. I know he has been carrying out his proposal and I think the results will be useful. Sir George has attended meetings—and probably dinners—of almost all our Local Centres. That is a very important function, because it enables the President to realize the points of view and the difficulties and aims of those Centres. Shortly after he entered the chair he unveiled the memorial plaque that was erected in Edinburgh by The Institution to Graham Bell, the founder of electric telephony. That function was very successfully broadcast and the speeches have been published in the *Journal*. In this connection I recall that in the year when I had the honour of being President I succeeded in getting Graham Bell, who was then in London, to attend one of our meetings and say a few words to us; and that was the last time, I think, he was ever in our Institution. Sir George gave at the Annual Dinner some interesting and amusing extracts which he had gathered from records in the

Post Office showing the early, and not altogether too warm, relations of the Post Office to our predecessors The Institution of Telegraph Engineers. Fortunately, and very largely due to the fact that the chief engineers who have been our Presidents have assisted to bring about a better state of affairs, we now have in our membership a very large contingent of Post Office engineers of all ranks, and they are among the most active and earnest of our supporters. With these few words I shall formally, but none the less warmly, move the resolution.

Mr. J. R. Beard: I am glad to join with Mr. Atkinson, and I am sure with all our 18 000 members, in thanking Sir George Lee for giving so freely to the service of our Institution those outstanding gifts which have carried him to one of the most important posts in the electrical engineering world. Those gifts are not only technical but administrative, with the result that under the recent re-organization scheme he is the first Engineer-in-Chief to be a member of the Post Office Board. He has been most enthusiastic and untiring in devotion to our interests and has taken a keen interest in the work of the Centres, culminating in the most successful Summer Meeting at the South Midland Centre. On Council, in Committee, and in that co-operation with other Institutions which appeals to him so much, his advice and guidance have been invaluable, and we have all appreciated that slight touch of ruthlessness which sweeps away the unessentials and concentrates both his own energy and that of his colleagues in keeping to the point and making speedy progress with the work in hand. We are beginning to realize that such a quality is essential to the efficient leadership of democracy in these difficult times, but Sir George also knows that impersonal efficiency is made still more efficient by the velvet glove, the golden voice, and the trust and respect of colleagues. Sir George can retire into the wings conscious of a part both well played and fully appreciated. I have very much pleasure in seconding the resolution.

The resolution was then carried with acclamation.

Sir George Lee: I am very grateful to Mr. Atkinson and Mr. Beard for the way in which they have proposed this vote of thanks, and to you for the way in which you have received it. Looking back over the past year of my presidency the many pleasurable incidents stand out very clearly, and they are connected almost entirely with the cordial assistance I have had from the Members of Council, from the Committee members, and from The Institution's permanent staff, Mr. Rowell and his assistants. Mr. Atkinson referred to one or two events which have taken place during the past year. I have found that the principal engineering Institutions welcome the idea of co-operation, and I am sure that it will go on. He has mentioned the unveiling of the Bell Memorial at Edinburgh: it gave me considerable pleasure to have that task to perform, and in view of my association with telecommunications it was quite a fortuitous but happy circumstance that it happened during my year of office as President. Finally, I should like to make a very special appeal on behalf of our Benevolent Fund. We have 18 000 members, and less than one-third subscribe to the Fund. I am quite sure that if the others knew of the good work which is being done by this Fund in the way of helping the families of members who have become sick, or out of work, or who have died, they would all subscribe.

Dr. A. P. M. Fleming, C.B.E., then delivered his Inaugural Address (see page 1).

Lieut.-Col. K. Edgcumbe: I should like first of all to congratulate the President on what I think must be a unique feat—that is to say, on delivering his Address without referring to a note and without hesitating for a word. One thing that greatly impressed me about the address was the way in which the President always put the man first and the system second. Others, speaking on the same subject, might have been tempted to stress the word " Education," spelt with a large E. I am not sure whether the President even used that word. What he spoke of throughout was the personnel and a training of that personnel suited to their particular requirements, and I venture to think that it is largely because of this distinction that Dr. Fleming has been so successful in the particular field that he adorns. He is one of those who believe that education was made for man, and not man for education. Dr. Inge said some years ago that contrary to the common idea that the most important function of education was to teach people to think for themselves, he considered an even more important function was to warn people when it was unsafe for them to think for themselves. I am sure that Dr. Fleming will agree with that view because I have often noticed that one of the most difficult problems of the research engineer was to convince the so-called " practical man " that it is very often quite unsafe for him to think for himself. Lastly, I should like to congratulate the President on his modesty. I do not think that anyone listening to his Address to-night would have realized the enormous contribution which he, and the body of men which he leads, have made to the progress of our industry during the last 20 years: and what a very large part of it has been placed unreservedly at the disposal of that industry as a whole. The resolution which I have to move is in these very inadequate words: " That the best thanks of The Institution be accorded to Dr. A. P. M. Fleming for his interesting and instructive Presidential Address, and that, with his permission, the Address be printed in the *Journal* of The Institution."

Prof. C. L. Fortescue: It is with the very greatest pleasure that I second the resolution. I have known Dr. Fleming for many years, and no one who has had that privilege can fail to appreciate the drive, the power, and the energy which he has put into the work of the last 40 years, and which he has described this evening. I feel that there will be a good many parts of the Address, when it is printed, which will have that property that all presidential addresses should have—namely, be thoroughly provocative. I feel that this vote of thanks is rather more than a formality with regard to the Address. It is our first opportunity of welcoming our new President, and I hope that that welcome, when I put this motion, will be a tumultuous one, for I know that our new President is deserving of it.

The vote of thanks was then carried with acclamation, and, after the President had briefly replied, the meeting terminated.

INSTITUTION NOTES

THE SECRETARY

Mr. P. F. Rowell has intimated to the Council that he desires to retire from the Secretaryship at the end of the present Session.

The Council have received his resignation with very much regret and are proceeding to the appointment of a successor. The following advertisement has been published in the technical and daily Press:—

THE INSTITUTION OF ELECTRICAL ENGINEERS.
APPOINTMENT OF SECRETARY.

The Council of The Institution of Electrical Engineers invite applications for the position of Secretary, which will become vacant on September 1st, 1939, owing to the retirement of the present Secretary. Applicants should be men, preferably between the ages of 35 and 45 years, of good education and personality who have had administrative experience. A knowledge of modern languages is desirable. The duties of the Secretary, who will be required to devote the whole of his time to the services of The Institution, are laid down in the following Bye-law:—

"Subject to the direction of the Council, it shall be the duty of the Secretary to conduct the correspondence of The Institution; to attend all meetings of The Institution, and of the Council, and of Committees; to take minutes of the proceedings of such meetings; to read all minutes and communications that may be ordered to be read; to superintend the publication of such papers and publications as the Council may direct; to have charge of the library; to direct the collection of the subscriptions and other amounts due to The Institution and the preparation of the account of the expenditure of the funds and to present all accounts to the Council for inspection and approval. He shall also engage, subject to the approval of the Council, and be responsible for all persons employed under him, and shall generally conduct the ordinary business of The Institution under the direction of the Council."

Commencing salary not less than £1 500 per annum. Contributory Staff Provident Scheme. Applications marked "Secretaryship" on both sides of the envelope should set forth particulars of education and experience in detail and should be addressed to the Chairman of the Selection Committee, The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2, not later than February 1st, 1939.

SUMMER MEETING, 1939

The Summer Meeting of The Institution will be held in Manchester and district from Monday, 19th June, to Friday, 23rd June, 1939, at the invitation of the Committee of the North-Western Centre.

Full particulars will be circulated as soon as they are available.

THE ENGINEERS' GERMAN CIRCLE

Monday, 20th February, 1939, at The Institution of Civil Engineers, Great George Street, Westminster, at 6 p.m. Lecture on "German Road Construction," by Dr. Todt, Director of Roads, and designer of the German State motor roads. The proceedings will be in German. The meeting is open to all I.E.E. members.

JOINT MEETING OF KINDRED SOCIETIES, 10th MARCH, 1938

The Council have accepted an invitation from The Institution of Automobile Engineers for the I.E.E. to participate in a Joint Meeting of Kindred Societies to be held on Friday, 10th March, 1939, when a discussion will take place on "Factors Contributing to Comfort in Travel." The subject will be dealt with from three aspects as follows:—

(*a*) "Road Travel" by Mr. Sidney E. Garcke.
(*b*) "Rail Travel" by the Rt. Hon. Lord Stamp, G.C.B., G.B.E.
(*c*) "Air Travel" by Captain E. W. Percival.

The meeting will be held in the Great Hall of The Institution of Civil Engineers, Great George Street, Westminster, S.W.1, at 7 p.m. (Light refreshments, 8.15 p.m. to 8.45 p.m.).

A limited supply of advance copies of the papers to be read will be available about one week before the meeting, and members desiring to receive copies should apply to the Secretary of the I.E.E., Savoy Place, London, W.C.2.

OVERSEAS MEMBERS AND THE INSTITUTION

During the period 1st June to 31st December, 1938, the following members from overseas called at The Institution and signed the "Attendance Register of Overseas Members":—

Ahern, P. J. (*Calcutta*).
Ahmed, A. A., D.Sc. (*Cairo*)
Anderson, B. B. (*Colombo*).
Antram, A. B. (*Abadan, Iran*).
Badcock, S. (*Johannesburg*).
Beckett, T. R., B.Sc.(Eng.) (*Kaduna, Nigeria*).
Black, K. H. (*Wellington, N.Z.*).
Bryl, Z., B.Sc.(Eng.) (*Warsaw*).
Bulow, V. A. M. (*Baghdad*).
Burkinshaw, H. (*Madras*).
Chantrill, R. L., B.Sc. (Eng.) (*Calcutta*).
Davidson, W. F., M.Sc. (*Brooklyn*).
Donkin, H. J., M.B.E. (*Delhi*).
Egerton, F. P. (*Kuala Lumpur, F.M.S.*).
Elliot, J. (*Lima*).
Fenton-Jones, H. (*Colombo*).
Forsyth, J. H., B.Sc. (*Modderfontein*).
Frazer, R. W. (*Lisbon*).
Geare, H. W. (*Cape Town*).
Gill, G. B. (*Hankow*).
Giorgi, Prof. G. (*Rome*).
Guilford, A. L., B.Sc.Tech. (*Bombay*).
Harpham, A. T. (*Salisbury, S. Rhodesia*).
Headland, H., M.Sc. (*Auckland, N.Z.*).
Jehu, J. W., B.Sc.Tech. (*Lagos*).
Jones, R. H., M.Sc. (*Accra, Gold Coast*).
Kopp, E. (*Haifa*).
Kulkarni, H. S. (*Calcutta*).
Lister, G. P. F. (*Insu, Gold Coast*).
Loria, C. A. (*Milan*).
MacIntyre, A. N. (*Calcutta*).
MacKay, D. H., B.Sc. (*Jerusalem*).
McNeil, P. D. (*Auckland, N.Z.*).
Marsh, E. R. (*Calcutta*).
Master, R. J. (*Hong Kong*).
Mellor, C. H. (*Shanghai*).
Melville, D. H. (*Valetta, Malta*).

Moody, H. T. (*Rangoon*).
Mukherji, R. G. (*Calcutta*).
Murray, G. A. (*Melbourne*).
Newling, V. H., B.Sc. (Eng.) (*Calcutta*).
Ogden, G. W., B.A., Captain, R. Signals (*Khartoum*).
Parsons, D. C. A. (*Auckland, N.Z.*).
Pienne, A. C. G. (*Ipoh, F.M.S.*).
Price, W., D.C.M. (*Bombay*).
Puttick, H. W. (*Lucknow*).
Rao, T. S., B.E. (*Lahore*).
Smith, W. E. (*Nairobi*).
Taylor, C. E. (*Västeras, Sweden*).
Taylor, W. T. (*São Paulo, Brazil*).
Thomas, A. O. (*Singapore*).
Thompson, N. A. (*Paris*).
Webb, G. F. (*Port Elizabeth*).
Webber, C. B. (*Funtua, Nigeria*).
Whitney, J. S. (*Shanghai*).
Willoughby, E. O., B.E.E., B.A. (*Singapore*).
Zaki, S. (*Cairo*).

LOCAL CENTRE COMMITTEES ABROAD

The present constitution of the Local Centre Committees abroad is as follows:—

Argentine

C. G. Barker (*Chairman*).
G. W. Munday (*Vice-Chairman*).

K. N. Eckhard.
C. W. Foale.
H. J. McPhail.
D. H. Nye.
H. C. Siddeley.
R. Wright.

R. G. Parrott (*Hon. Secretary*).

China

S. Flemons (*Chairman*).
W. C. Gomersall (*Vice-Chairman*).

W. A. Ankerson.
S. Y. Chang, M.Sc.
F. J. Hookham, B.Sc.
J. A. McKinney.
W. L. E. Miller.
A. J. Percival.
C. R. Webb.
W. H. Wei.
J. Haynes Wilson, M.C.

W. Miles (*Hon. Secretary*).

OVERSEAS COMMITTEES

The present constitution of the Overseas Committees is as follows:—

Australia

New South Wales.

V. L. Molloy (*Chairman*).

V. J. F. Brain, B.E.
L. F. Burgess, M.C.
W. R. Caithness.
E. F. Cambell, B.Eng.
R. V. Hall, B.E.
A. S. Plowman.
P. S. Saunderson.

W. J. McCallion, M.C. (*Hon. Secretary*).

Queensland.

J. S. Just (*Chairman and Hon. Secretary*).

W. Arundell.
E. B. Freeman.
F. R. L'Estrange.
L. G. Pardoe.

South Australia.

F. W. H. Wheadon (*Chairman and Hon. Secretary*).

J. R. Brookman, M.E.
E. V. Clark.
J. S. Fitzmaurice.
Sir W. G. T. Goodman.
W. Inglis.
J. C. Stobie.

Victoria and Tasmania.

H. R. Harper (*Chairman and Hon. Secretary*).

F. W. Clements.
J. M. Crawford.
H. C. Newton.
T. P. Strickland.
R. J. Strike.

Western Australia.

J. R. W. Gardam (*Chairman*).

F. C. Edmondson.
Prof. P. H. Fraenkel, B.E.
S. Johnson.
W. H. Taylor.

A. E. Lambert, B.E. (*Hon. Secretary*).

Ceylon

Major C. H. Brazel, M.C. (*Chairman*).

C. H. Jones.
A. T. Kingston.
G. L. Kirk.
D. Lusk.
G. E. Misso.
R. H. Paul.
J. Shillitoe.
E. H. Targett.

D. P. Bennett (*Hon. Secretary*).

India

Bombay.

R. G. Higham (*Chairman*).

C. M. Cock.
K. M. Dordi.
N. R. Khambati.
E. G. Lazarus.
G. L. Rhodes, M.A.

A. L. Guilford, B.Sc.Tech. (*Hon. Secretary*).

Calcutta.

F. T. Homan (*Chairman*).

K. N. Arnold.
N. C. Bhattacharji.
C. R. Bland.
H. J. Darling.
E. B. C. Preston.
S. W. Redclift.
Prof. F. W. Sharpley, F.R.S.E.
K. G. Sillar.

D. H. P. Henderson (*Hon. Secretary*).

Lahore.

V. F. Critchley (*Chairman*).

M. A. Haque.
Prof. T. H. Matthewman.
S. S. Kumar, M.Sc.(Eng.).
P. N. Mukerji, M.Sc.
T. S. Rao, B.E.
S. Singh, M.Sc.
N. Thornton.

J. C. Brown (*Hon. Secretary*).

Madras.

E. J. B. Greenwood (*Chairman and Hon. Secretary*).

L. Henshaw.
R. M. Steele.

New Zealand

F. T. M. Kissel, B.Sc. (*Chairman*).

R. H. Bartley.
M. C. Henderson.
E. Hitchcock.

J. McDermott (*Hon. Secretary*).

South Africa

Transvaal.

W. Elsdon Dew (*Chairman and Hon. Secretary*).

J. B. Bullock.
S. E. T. Ewing.
V. Pickles.
B. Price.
Prof. O. R. Randall, Ph.D., M.Sc.
A. Rodwell.
L. B. Woodworth.

COMMITTEES, 1938–1939*

Meter and Instrument Section Committee

Chairman: Captain B. S. Cohen, O.B.E.
Vice-Chairman: F. E. J. Ockenden.
Immediate Past-Chairman: H. Cobden Turner.

H. M. Barlow, Ph.D.	C. W. Hughes, B.Sc.
L. C. Benton.	F. J. Lane, M.Sc.
J. W. Carter.	C. G. Mayo, M.A., B.Sc.
A. Felton, B.Sc.(Eng.).	E. H. Miller.
J. L. Ferns, B.Sc.	W. Phillips.
E. Grundy, B.Sc.(Tech.).	A. E. Quenzer.

And

A representative of the Council.
The Chairman of the Papers Committee.

Transmission Section Committee

Chairman: S. R. Siviour.
Vice-Chairman: F. W. Purse.
Immediate Past-Chairman: J. L. Eve.

H. J. Allcock, M.Sc.	Prof. W. J. John, B.Sc. (Eng.).
C. F. Bolton.	J. S. Pickles, B.Sc.Tech.
W. M. Booker.	P. E. Rycroft, M.B.E.
N. K. Bunn.	T. R. Scott, B.Sc.
N. Cresswell.	H. Willott Taylor.
P. K. Davis.	

And

A representative of the Council.
The Chairman of the Papers Committee.
The following representatives of Government Departments:—
Central Electricity Board: C. W. Marshall, B.Sc.
Electricity Commission: H. W. Grimmitt.
Post Office: P. B. Frost, B.Sc.(Eng.).

Wireless Section Committee

Chairman: A. J. Gill, B.Sc.(Eng.).
Vice-Chairman: H. Bishop, C.B.E., B.Sc.(Eng.).
Immediate Past-Chairman: T. Wadsworth, M.Sc.

W. J. Brown, B.Sc.	J. S. McPetrie, B.Sc., Ph.D.
R. P. G. Denman, M.A.	E. B. Moullin, M.A.
T. E. Goldup.	Col. G. D. Ozanne, M.C.
A. J. A. Gracie, B.Sc.	W. J. Picken.
H. L. Kirke.	S. B. Smith.
G. S. C. Lucas.	R. T. B. Wynn, M.A.

And

A representative of the Council.
The Chairman of the Papers Committee.
The following representatives of Government Departments:—
Admiralty: Capt. P. F. Glover, R.N.
Air Ministry: N. F. S. Hecht.
Post Office: A. H. Mumford, B.Sc.(Eng.).
War Office: Col. R. Elsdale, O.B.E., M.C.

Among the committees appointed by the Council for 1938–39 are the following:—

The President is, *ex-officio*, a member of all Committees of The Institution.

Benevolent Fund Committee

The President (*Chairman*).

T. Carter .. .. Prof. R. O. Kapp, B.Sc. .. .. P. J. Robinson, M.Eng. .. .. J. W. Thomas, LL.B., B.Sc.Tech. A. P. Young	representing the Council.
H. T. Young .. .. .. A. L. Lunn .. .. .. H. Marryat .. .. .. W. C. P. Tapper	representing the Contributors.

And the Chairman of each Local Centre in Great Britain and Ireland.

Informal Meetings Committee

P. P. Wheelwright (*Chairman*).

S. C. Bartholomew, M.B.E.	A. G. Kemsley.
J. R. Beard, M.Sc.	W. A. Ritchie.
H. Brierley.	F. Jervis Smith.
A. F. Harmer.	M. Whitgift.
J. R. Jones.	

And

A representative of the General Purposes Committee.
The Chairman of the Papers Committee.
The Chairman of the London Students' Section.

Joint Committee for National Certificates and Diplomas in Electrical Engineering (England and Wales)

Prof. C. L. Fortescue, O.B.E., M.A. J. W. Thomas, LL.B., B.Sc.Tech. Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng.	representing the I.E.E.
F. T. Chapman, D.Sc. .. .. H. E. Dance, M.Eng. .. .. H. J. Shelley, B.Sc.	representing the Board of Education.

Joint Committee for National Certificates and Diplomas in Electrical Engineering (Scotland)

Prof. G. W. O. Howe, D.Sc. D. S. Munro .. .. .. R. Robertson, B.Sc. .. .. Prof. S. Parker Smith, D.Sc.	representing the I.E.E.
Dr. J. S. W. Boyle .. .. J. Ferguson .. .. .. J. G. Frewin .. .. .. W. Hyslop	representing the Scottish Education Department.

Local Centres Committee

J. R. Beard, M.Sc.	Col. Sir Thomas F. Purves, O.B.E.
T. Carter.	W. B. Woodhouse.
F. Forrest.	H. T. Young.
H. Hooper.	

And the Chairman of each Local Centre and Sub-Centre.

Overseas Activities Committee

Sir Noel Ashbridge, B.Sc.(Eng.).	W. G. Hendrey.
Lieut.-Col. K. Edgcumbe, T.D.	C. le Maistre, C.B.E.
F. Gill, O.B.E.	C. C. Paterson, O.B.E., D.Sc.

And

The Chairman of the Finance Committee.
The Chairman of the General Purposes Committee.
The Chairman of the Membership Committee.
The Chairman of the Papers Committee.

Also the following co-opted members:—

J. W. Bell.
Prof. J. K. Catterson-Smith, M.Eng.
W. P. Gauvain.
A. S. Herbert.
A. C. Holtby.
A. C. Kelly.
F. Lydall.
J. T. Mertens.
E. A. Mills.
H. Nimmo.
E. E. Sharp.
A. L. Stanton.
C. S. Taylor.
V. Watlington, M.B.E.

Scholarships Committee

Prof. J. K. Catterson-Smith, M.Eng.
J. M. Donaldson, M.C.
F. Forrest.
Prof. J. T. MacGregor-Morris.
Prof. E. W. Marchant, D.Sc.
H. Marryat.
Johnstone Wright.
A. P. Young.

"Science Abstracts" Committee

T. E. Allibone, D.Sc., Ph.D.
L. G. Brazier, Ph.D., B.Sc.
Prof. E. W. Marchant, D.Sc.
C. C. Paterson, O.B.E., D.Sc.

And	*Representing*
J. H. Awbery, B.A., B.Sc.; Prof. A. Ferguson, M.A., D.Sc.; D. Owen, B.A., D.Sc.; W. Jevons, D.Sc., Ph.D.	Physical Society.
Prof. G. P. Thomson, M.A., F.R.S.	Royal Society.

Ship Electrical Equipment Committee

A. G. S. Barnard.
Major B. Binyon, O.B.E., M.A.
J. H. Collie.
Dr. P. Dunsheath, O.B.E., M.A.
S. Harcombe, M.A., B.Sc.
A. Henderson.
J. F. W. Hooper.
P. V. Hunter, C.B.E.
F. Johnston.
J. W. Kempster.
A. Cecil Livesey.
S. W. Melsom.
N. W. Prangnell.
Col. A. P. Pyne.
C. Rodgers, O.B.E., B.Sc., B.Eng.
F. A. Ross.
T. A. Sedgwick.
H. D. Wight.
H. A. Wilson.

And	*Representing*
J. S. Pringle, O.B.E.	Admiralty.
H. Cranwell; W. T. Williams, O.B.E.	Board of Trade.
B. Hodgson; J. Turnbull	British Corporation Register of Shipping and Aircraft.
T. Ratcliffe, M.Sc.Tech.; C. W. Saunders	British Electrical and Allied Manufacturers' Association.
E. W. Andrews	Electrical Contractors' Association.
S. A. Smith, M.Sc.; N. H. Swancoat	The Institute of Marine Engineers.
J. F. Nielson	Institution of Engineers and Shipbuilders in Scotland.
W. J. Belsey	Institution of Naval Architects.
S. F. Dorey, D.Sc.; G. O. Watson	Lloyd's Register of Shipping.
W. S. Wilson	North-East Coast Institution of Engineers and Shipbuilders.
(To be nominated)	Electrical Contractors' Association of Scotland.

Wiring Regulations Committee

Ll. B. Atkinson.
H. J. Cash.
J. R. Cowie.
Dr. P. Dunsheath, O.B.E., M.A.
W. Fennell.
R. Grierson.
J. F. W. Hooper.
P. V. Hunter, C.B.E.
H. Marryat.
F. W. Purse.
Col. A. P. Pyne.
E. Ridley, M.B.E.
P. L. Rivière.
J. F. Stanley, B.Sc.(Eng.).
H. W. Swann.

And	*Representing*
L. Pyke	Association of Consulting Engineers.
A. Kirk	Association of Supervising Electrical Engineers.
E. B. Wedmore, C.B.E.	British Electrical and Allied Industries Research Association.
C. A. Martin; C. Rodgers, O.B.E., B.Sc., B.Eng.; T. M. H. Stubbs; J. B. Tucker; A. J. L. Whittenham	British Electrical and Allied Manufacturers' Association.
W. F. Bishop; S. W. Melsom	Cable Makers' Association.
G. F. A. Norman; E. A. Reynolds, M.A.	Electrical Contractors' Association.
R. A. Ure	Electrical Contractors' Association of Scotland.
E. S. Hodges; E. B. Hunter; W. H. Tuckey	Fire Offices Committee.
A. J. McColgan	Home Office.
R. W. L. Phillips; J. W. J. Townley	Incorporated Municipal Electrical Association
E. W. Farr	Independent Cable Makers' Association.

REPRESENTATIVES OF THE INSTITUTION ON OTHER BODIES

The following is a list of representatives of The Institution on other bodies, and gives the dates on which they were appointed:—

Admiralty:

Selection Committee for Vacancies for Assistant Electrical Engineers:

R. T. Smith (1 July, 1937).

Bristol University:

H. F. Proctor (8 Jan., 1925).

British Cast Iron Research Association:

E. B. Wedmore, C.B.E. (25 Sept., 1924).

British Electrical and Allied Industries Research Association:

Council:

J. M. Donaldson, M.C. (18 Dec., 1930).
C. P. Sparks, C.B.E. (18 Dec., 1930).

Sub-Committee on Connections to Large Gas-filled Lamps:

C. C. Paterson, O.B.E., D.Sc. (24 Oct., 1929).
B. Welbourn (24 Oct., 1929).

Sub-Committee on Earthing and Earth Plates:

S. W. Melsom (31 Jan., 1930).

British Electrical Development Association: Committee on Rural and Agricultural Electrification:

J. M. Donaldson, M.C. (20 Oct., 1927).
R. Grierson (20 Oct., 1927).

British Standards Institution:

Engineering Divisional Council:

Sir George Lee, O.B.E., M.C. (22 April, 1937).
C. C. Paterson, O.B.E., D.Sc. (10 March, 1938).
W. B. Woodhouse (19 March, 1936).

Electrical Industry Committee:

Lt.-Col. K. Edgcumbe, T.D. (5 March, 1925).
F. Gill, O.B.E. (21 May, 1914).
J. S. Highfield (21 May, 1914).
E. H. Shaughnessy, O.B.E. (23 March, 1933).
R. T. Smith (21 May, 1914).

Technical Committee on Cables:

E. B. Hunter (20 Oct., 1938).
Col. A. P. Pyne (3 Nov., 1938).
G. O. Watson (20 Oct., 1938).
H. D. Wight (20 Oct., 1938).

Technical Committee on Electric Clocks:

E. B. Hunter (5 Dec., 1935).

Technical Committee on Electric Power Cables:

S. W. Melsom (10 Jan., 1930).

Technical Committee on Electric Signs:

L. Barlow (14 May, 1931).
R. W. L. Phillips (17 Feb., 1932).

Technical Committee on Electrical Accessories:

H. J. Cash (31 March, 1925).
F. W. Purse (31 March, 1925).

Technical Committee on Electrical Instruments:

Lt.-Col. K. Edgcumbe, T.D. (15 Feb., 1923).

Technical Committee on Electrical Nomenclature and Symbols:

C. C. Paterson, O.B.E., D.Sc. (8 Jan., 1920).

Technical Committee on Electricity Meters:

A. J. Gibbons, B.Sc.Tech. (28 March, 1930).
O. Howarth (22 Oct., 1936).
G. F. Shotter (28 Feb., 1929).

British Standards Institution—*continued.*

Technical Committee on Identification of Pipe-lines in Buildings:

R. Grierson (11 May, 1933).

Technical Committee on Lifts, Hoists, and Escalators:

H. Marryat (25 Oct., 1934).

Technical Committee on Overhead Transmission Lines Material:

J. L. Eve (11 Nov., 1936).

Technical Committee on Provision in Buildings for Ducts for Service Pipes:

H. J. Cash (1 Dec., 1938).
E. B. Hunter (1 Dec., 1938).

Technical Committee on Regulations for Overhead Lines:

W. Fennell (23 April, 1936).
S. R. Siviour (23 April, 1936).

Technical Committee on Safety Requirements:

H. J. Cash (22 Oct., 1936).
R. W. L. Phillips (22 Oct., 1936).
E. Ridley, M.B.E. (11 Feb., 1937).

Technical Committee on Testing and Expressing the Overall Performance of Radio Receivers:

R. P. G. Denman, M.A. (21 Oct., 1937).

Technical Committee on Under-Floor Duct Systems:

E. B. Hunter (22 Oct., 1936).
H. W. Swann (22 Oct., 1936).

Technical Committee on Wireless Apparatus and Components:

E. H. Shaughnessy, O.B.E. (30 Sept., 1925).

Sub-Committee on Automatic Change-Over Switches for Emergency Lighting Systems:

E. Ridley, M.B.E. (22 Oct., 1936).

Sub-Committee on Cables for Use on Board Ship:

E. B. Hunter (20 Oct., 1938).
Col. A. P. Pyne (3 Nov., 1938).
G. O. Watson (20 Oct., 1938).
H. D. Wight (20 Oct., 1938).

Sub-Committee on Ceiling Roses:

H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

Sub-Committee on Conduit Fittings:

H. J. Cash (18 May, 1927).

Sub-Committee on Connectors for Portable Appliances:

H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 May, 1937).

Sub-Committee on Connectors for Radio Apparatus:

R. W. L. Phillips (6 Jan., 1931).

Sub-Committee on Copper Conduit Tubes (Light Gauge):

H. Marryat (17 Dec., 1936).

Sub-Committee on Cut-outs for Radio Receivers:

S. W. Melsom (5 Dec., 1935).

British Standards Institution—*continued.*

Sub-Committee on Distribution Boards:
E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).

Sub-Committee on Fuses:
H. J. Cash (22 June, 1926).
E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).

Sub-Committee on Instrument Transformers:
G. F. Shotter (22 Feb., 1934).

Sub-Committee on Lead Alloys for Cable Sheathing:
B. Welbourn (22 June, 1933).

Sub-Committee on Letter Symbols:
A. T. Dover (21 Nov., 1929).

Sub-Committee on Light-Gauge Copper Tubes for Electrical Conduits:
H. Marryat (17 Dec., 1936).

Sub-Committee on Low-Voltage Transformers for Lighting Equipment and Bell-Ringing Circuits:
G. F. A. Norman (11 Feb., 1937).

Sub-Committee on Mains Supply Apparatus for Radio Receivers, etc.:
R. W. L. Phillips (11 Dec., 1930).
F. W. Purse (16 Oct., 1928).

Sub-Committee on Non-Ignitable and Self-Extinguishing Boards for Electrical Purposes:
S. W. Melsom (24 Oct., 1935).
E. Ridley, M.B.E. (24 Oct., 1935).

Sub-Committee on Protected-type Plugs and Sockets:
H. J. Cash (26 Oct., 1932).
F. W. Purse (26 Oct., 1932).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Radio Interference from Trolley-Buses and Tramcars:
C. C. Paterson, O.B.E., D.Sc. (7 Nov., 1935).
H. Wallis (7 Nov., 1935).

Sub-Committee on Radio Nomenclature and Symbols:
Col. A. S. Angwin, D.S.O., M.C., B.Sc.(Eng.) (7 April, 1932).

Sub-Committee on Telephone and Radio Connectors:
R. W. L. Phillips (28 Feb., 1935).
A. J. L. Whittenham (28 Feb., 1935).

Sub-Committee on Tumbler Switches:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

Sub-Committee on Wall-plugs and Sockets:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Welding Plant and Equipment.
Major J. Caldwell, J.P. (26 Oct., 1933).

British Standards Institution—*continued.*

Panel on Graphical Symbols for Interior Installations:
G. F. A. Norman (11 Feb., 1937).
E. Ridley, M.B.E. (11 Feb., 1937).

Colliery Requisites Industry Committee:
C. T. Allan (3 July, 1924).

Technical Committee on Mining Electrical Plant:
A. C. Sparks (27 March, 1930).

Birmingham Regional Committee:
F. C. Hall.

Glasgow Regional Committee:
F. Anslow.

Manchester Regional Committee:
W. T. Anderson.

Newcastle Regional Committee:
S. A. Simon, B.A.

Sheffield Regional Committee:
M. Wadeson.

Technical Committee for Co-ordinating the Work on Units and Quantities of the Building, Chemical, and Engineering Divisional Councils:
E. B. Wedmore, C.B.E. (3 Feb., 1938).

Technical Committee on Coal:
W. M. Selvey (19 Jan., 1928).

Technical Committee on Engine Testing Fittings:
W. M. Selvey (22 Oct., 1931).

Technical Committee on Engineering Symbols and Abbreviations:
A. T. Dover (21 Nov., 1929).

Technical Committee on Fans:
Prof. R. O. Kapp, B.Sc. (22 Oct., 1931).

Technical Committee on Land Boilers:
W. M. Selvey (7 April, 1932).

Technical Committee on Larch Poles:
B. Welbourn (21 Jan., 1932).

Technical Committee on Lightning Conductors:
Prof. W. M. Thornton, O.B.E, D.Sc., D.Eng. (30 Jan., 1936).

Technical Committee on Measurement of Temperature, Flow, and Pressure of Fuel and Flue Gases:
G. A. Whipple, M.A. (28 April, 1938).

Technical Committee on Methods of Test for Dust Extraction Plant:
C. L. Blackburn, B.A. (25 Oct., 1934).

Technical Committee on Pipe Flanges:
W. M. Selvey (14 April, 1921).

Technical Committee on Pump Tests:
R. S. Allen (2 July, 1931).

British Standards Institution—*continued.*

Technical Committee on Railway Signalling Apparatus:

A. F. Bound (24 Oct., 1929).

Technical Committee on Rating of Rivers:

G. K. Paton (20 Oct., 1927).

Technical Committee on Rubber Belting:

C. Rodgers, O.B.E., B.Sc., B.Eng. (5 Jan., 1928).

Technical Committee on Traction Poles:

T. L. Horn (4 Feb., 1926).

Sub-Committee on Accessories for Land Boilers:

W. M. Selvey (7 April, 1932).

Sub-Committee on Boiler and Superheater Tubes:

W. M. Selvey (7 April, 1932).

Sub-Committee on Fittings for Land Boilers:

W. M. Selvey (7 April, 1932).

Sub-Committee on Water-Tube Boilers:

W. M. Selvey (7 April, 1932).

Sub-Committee on Portable Railway Track:

R. T. Smith (25 Oct., 1928).

Illumination Industry Committee:

Lt.-Col. K. Edgcumbe, T.D. (28 Feb., 1924).
P. Good (28 Feb., 1924).
H. W. Gregory (26 Oct., 1933).
Prof. J. T. MacGregor-Morris (28 Feb., 1924).
J. W. J. Townley (16 May, 1935).

Building Industry, National Council for: Advisory Committee on Building Acts and Bye-Laws:

F. W. Purse (20 Oct., 1932).
H. T. Young (20 Oct., 1932).

City and Guilds of London Institute:

Advisory Committee on Electrical Engineering Practice:

Prof. E. W. Marchant, D.Sc. (22 June, 1933).

Advisory Committee on Electrical Installation Work:

Prof. S. Parker Smith, D.Sc. (20 Oct., 1927).

Advisory Committee on Illuminating Engineering Examinations:

C. C. Paterson, O.B.E., D.Sc. (8 April, 1937).

Advisory Committee on Telecommunications:

E. H. Shaughnessy, O.B.E. (22 Oct., 1931).

Fellowship Committee:

W. H. Eccles, D.Sc., F.R.S. (19 April, 1928).

Council for the Preservation of Rural England:

J. M. Kennedy, O.B.E. (10 Jan., 1929).

Electrical Association for Women:

Council:

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (18 Dec., 1924).

Committee for Training of Women Demonstrators:

J. R. Beard, M.Sc. (4 Nov., 1937).

Engineering Joint Council:

J. M. Kennedy, O.B.E. (20 Feb., 1936).
H. T. Young (24 Feb., 1938).

Engineering Joint Examination Board:

Prof. C. L. Fortescue, O.B.E., M.A. (24 Mar., 1938).
Prof. R. O. Kapp, B.Sc. (3 Nov., 1938).

Engineering Public Relations Committee:

J. M. Kennedy, O.B.E. (6 May, 1937).

Registration of Engineers Sub-Committee:

J. M. Kennedy, O.B.E. (20 Oct., 1938).

Sub-Committee for Scotland:

Major H. Bell, O.B.E., T.D. (23 May, 1938).

H.T. Conference, Paris: British National Committee:

F. H. Clough, C.B.E., (10 Mar., 1938).
A. H. Railing, D.Eng. (10 Mar., 1938).

Imperial College of Science and Technology: Governing Body:

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (20 Oct., 1938).

Imperial Minerals Resources Bureau Conference: Copper Committee:

B. Welbourn (18 Sept., 1919).

Institute of Industrial Administration: Examinations Advisory Council:

A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Oct., 1934).

Institute of Metals: Corrosion Research Committee:

W. M. Selvey (19 July, 1923).

Institution of Civil Engineers:

Engine and Boiler Testing Committee:

C. P. Sparks, C.B.E. (19 Oct., 1922).

Earthing to Water Mains Sub-Committee:

Ll. B. Atkinson (20 Feb., 1936).
P. Dunsheath, O.B.E., M.A., D.Sc. (20 Feb., 1936).
F. W. Purse (20 Feb., 1936).
P. J. Ridd (20 Feb., 1936).

International Association for Testing Materials:

J. M. Kennedy, O.B.E. (5 July, 1928).

International Engineering Congress, Glasgow, 1938:

General Committee:

H. C. Babb (8 April, 1937).
J. Miller (8 April, 1937).
R. B. Mitchell (8 April, 1937).
P. F. Rowell (*ex officio*) (8 April, 1937).

London Committee:

J. R. Beard, M.Sc. (6 May, 1937).
P. F. Rowell (*ex officio*) (6 May, 1937).

Glasgow Committee:

J. Miller (13 April, 1937).
P. F. Rowell (*ex officio*) (13 April, 1937).

International Illumination Commission: British National Committee:
Lt.-Col. K. Edgcumbe, T.D. (27 Nov., 1913).
P. Good (18 Sept., 1919).
H. W. Gregory (26 Oct., 1933).
Prof. J. T. MacGregor-Morris (27 Nov., 1913).
J. W. J. Townley (16 May, 1935).

Joint Committee of the British Electrical and Allied Industries Research Association and The Institution of Civil Engineers, for Research on Earthing to Water Mains:
C. W. Marshall, B.Sc. (24 Feb., 1938).
F. W. Purse (3 Feb., 1938).
W. G. Radley, Ph.D.(Eng.) (3 Feb., 1938).

Joint Committee on Engineering Co-operation Overseas:
F. Gill, O.B.E. (28 April, 1938).

Joint Committee on Materials and their Testing:
S. W. Melsom (16 July, 1938).

Joint Fuel Committee:
C. P. Sparks, C.B.E. (7 Jan., 1932).

Loughborough Technical College: Advisory Committee:
Ll. B. Atkinson (11 April, 1929).

Manchester Regional Advisory Council for Technical and other Forms of Further Education:
J. W. Thomas, LL.B., B.Sc.Tech. (20 Jan., 1938).
A. Morris (20 Jan., 1938).
L. H. A. Carr, M.Sc.Tech. (20 Jan., 1938).

Metalliferous Mining (Cornwall) School: Governing Body:
L. A. Hards (1 Dec., 1927).

National Physical Laboratory: General Board:
J. M. Donaldson, M.C. (7 Nov., 1935).
Dr. P. Dunsheath, O.B.E., M.A. (3 Nov., 1938).

National Register of Electrical Installation Contractors:
H. J. Cash (12 March, 1931).
P. V. Hunter, C.B.E. (18 Feb., 1926).
W. R. Rawlings (18 Feb., 1926).
W. M. Selvey (18 Feb., 1926).

National Smoke Abatement Society:
H. C. Lamb (26 Oct., 1933).
C. D. Taite (26 Oct., 1933).

Professional Classes Aid Council:
P. F. Rowell (20 April, 1928).

Royal Engineer Board:
W. B. Woodhouse (19 March, 1925).

Royal Society:
National Committee on Physics:
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng. (19 Nov., 1936).

Royal Society—*continued.*
National Committee for Scientific Radio:
Prof. C. L. Fortescue, O.B.E., M.A. (19 Nov., 1936).
E. H. Rayner, M.A., Sc.D. (9 Nov., 1933).

Science Museum, South Kensington: Advisory Council:
C. C. Paterson, O.B.E., D.Sc. (1 July, 1937).

Town Planning Institute: Committee on Overhead Transmission Lines:
J. M. Kennedy, O.B.E. (7 April, 1932).

Union of Lancashire and Cheshire Institutes (Panel for Engineering):
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (28 Feb., 1924).
Prof. Miles Walker, M.A., D.Sc., F.R.S. (28 Feb., 1924).

University College, Nottingham: Electrical Engineering Advisory Committee:
A. D. Phillips (23 Feb., 1933).

War Office Mechanization Board:
W. H. Eccles, D.Sc., F.R.S. (19 Jan., 1928).

Women's Engineering Society:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Sept., 1924).

World Power Conference (British National Committee):
Sir Archibald Page (28 April, 1938).

ELECTIONS AND TRANSFERS

At the Ordinary Meeting of The Institution held on the 3rd November, 1938, the following elections and transfers were effected:—

Elections

Associate Members

Ballard, Walter George.
Britton, Alfred David.
Carey, Arthur Edwin G.
Collingbourne, Herbert Lawrence.
Collins, Henry Edward, M.Eng.
Cox, Harold Ernest.
Crowley, Cornelius.
Davis, Norman Eustace.
Dimmick, Roland George A., B.Sc.
Draper, Alec, B.Sc.(Eng.).
Fayle, Lindley Robert E., Capt. R.E.
Ferguson, Bryan.
Gilchrist, William.
Hills, Herbert Frank.
Hudson, Robin Turnour.
Kent, Wilfrid Robin L., B.A.
Kinross, Rupert Ivor.
Knell, Harold Frederick.
Machanik, Phillip, B.Sc. (Eng.), M.Sc.
Mitchell, Charles Arthur.
Pinder, John.
Robertson, Cecil David S. G.
Rycroft, David Maxwell, Capt., R.E.
Shaw, Hubert.
Smith, George Edgar.
Spagnoletti, Philip Hylton, B.A.
Stewart, Walter.
Taylor, Alexander.
Topham, Charles Lonsdale.
Ward, Edmund.
Wood, Bernard Harold, B.Sc.
Wray, John Alan.
Young, Reginald Seymour, Lieut.-Commander.

Companions

Lyons, Claude Lipman.
Pole, Sir Felix John C.

Associates

Burnett, George William.
Capper, Sam.
Clayton, Gordon Albert.
Davis, Joseph Jacob.
Daw, Reginald.
Hancock, William Henry.
Jenkins, Russel Mander.
Jones, Alexander Harman.
Miller, David.
Parsons, Prichard Thomas.
Smith, James Samuel, Flying Officer, M.B.E.
Stevenson, Charles Leonard.
Thomas, Alfred Morris, B.Sc.

Graduates

Arbuckle, John Thomas, B.Sc.
Asbury, Allan, B.Sc.
Atkinson, David.
Axford, Arthur John.
Bancroft, Thomas Frederick.
Bartho, Percival Horatio, B.Sc.(Eng.).
Birch, Frank.
Bottoms, Raymond Frederick.
Brocklesby, Harry.
Bruce, Donald Marsh, B.Sc.(Eng.).
Calvert, Richard Lutton, B.Sc.
Carruthers, John.
Carter, Andrew Laurence P., B.A.
Chu, Lincoln Shi C., B.Sc.
Collins, Clifford William.
Crispin, John Arnold, B.Sc. Tech.
Drake, Leslie Scott.
Dwolatzky, Sidney, B.Sc. (Eng.).
Fay, Francis Sidney, B.A.
Gardner, Stanley Douglas.
Gee, Edgar Ernest, B.Sc.
Gilbert, John Reginald.
Godbold, Brian Craig, B.Sc.
Goodman, Kenneth George.
Guha, Pares Chandra, B.Sc. (Eng.).
Gwyn, David Glanville, B.Sc.(Eng.).
Hodges, Leonard Allen.
Haslam, James Firth.
Hornby, Frank, B.Sc.(Eng.).
Khanna, Mangal Sen.
Kibblewhite, Geoffrey George, B.Sc.(Eng.).
Mirfield, Theon Numa, B.E.E.
Oglesby, Clifford George, B.Eng.
Parker, Harry Coulston, B.Sc.
Patel, Natverlal Lalaji, B.Sc.
Pickup, Rupert William, B.Sc.
Pitt, Cyril Kenneth.
Probert, Gurney Oliver, B.A.
Qualtrough, Joseph Mylchreest, B.Sc.
Reeve, Jack Oliver, B.Sc.
Rivett, Bernard Henry D.
Robertson, William.
Sahai, Basudeo, B.Eng.
Shekhdar, Nariman Maneckji.
Sinclair, Douglas Bruce.
Tomlinson, Albert Walter.
Unwin, Horace Jack.
Vij, Kasturi Lal.
Waring, Victor Alexander T., B.Sc.
Wase, Arthur Edward N.
Williams, William Harold.

Students

Adcock, Harold John.
Aish, Norman Cyril R.
Andrews, Kenneth Ralph.
Arthur, Enoch.
Baird, William James.
Barth, Arthur Harold.
Bayford, Leslie John.
Betts, Peter, B.Sc.
Bolton, Thomas Gilbert B.
Brion, Edwin Alfred.
Brown, Richard Henry.
Calmeyer, Reginald.
Chappel, Mervyn Joseph W.
Choombala, Choompakabutra.
Clinch, Charles Ernest E.
Cohen, Joseph Hyeem L.
Cousins, Norman James.
Davies, William Griffith.
Duckett, George Eric.
Durrant, Edward Geoffrey.

Students—continued.

Edelsten, William Keith.
Elliott, Kenneth Douglas.
Ellis, William Arthur.
Field, Peter.
Ford-Hutchinson, Peter William S.
Fryer, Cyril Herbert.
Galland, Raymond Harry.
Halliday, Cecil, B.Sc.
Harvey, Ronald Alfred.
Harvey, William Ernest.
Hassall, Alan James.
Heath, Frederick Walter.
Higham, James Berry.
Horner, Kenneth William.
Howard, Leslie Charles.
Hunt, Henry Norman.
Jenkins, Herbert George.
Jolliffe, Sidney Arthur W.
Kerr, Geoffrey Hall.
Knight, Vincent Stanley N.
Lea, Charles Arthur.
Lewis, John Beresford.
McIndoe, William Arthur.
Malik, Amrik Singh.
Manuel, Charles Anthony.
Martens, Alwyn.
Martin, Kenneth Spencer.
Moseley, William Barrie.
Mulleneux, Phillip Adrian.
Newton, Harold Edward.
Norris, Edgar Charles.
Oldridge, Roy.
Peart, Harry.
Peel, Edwin.
Phipps, Albert William.
Powell, Eric.
Pratt-Johnson, William Henry.
Prescott, Colin.
Priest, Frederick Ian D.
Pybus, Jack, M.Sc.
Redmayne, William Eric.
Robertson, William Blair.
Robinson, Stanley.
Ross, Norman Lang.
Savill, George Frederick.
Sells, Donald Jack.
Shipstone, Bernard Arthur.
Sills, Frederick Arthur.
Smith, John Keetley.
Stafford, Clifford Reginald.
Stapleton, Robert.
Stefani, Ivan Laurence.
Sturge, Geoffrey Howard.
Summerley, Denis Lansdowne.
Tait, Ernest John S.
Templeman, Robert William.
Wertheim, Bernard Louis.
Whalley, William Henry.
Wilkinson, Harry.
Williams, John Herbert.

Transfers

Associate Member to Member

Birt, Ronald, B.Sc.(Eng.).
Bryden, James Emmanuel, B.Sc.(Eng.).
Burrell, Fountain Meers.
Chinn, William Ernest.
Coward, Arthur Langdale.
Dobeson, Richard Gray, B.Sc.
Edmondson, Francis Charles.
Gadkary, Sadashiv Atmaram.
Haws, John Haywood.
Hippisley, Edward Townsend, Capt., M.A.
Main, Francis Walter.
Newburn, Edgar Allan.
Peters, William Herbert, B.Sc.(Eng.).
Shuttleworth, Charles Irwin.
Warren, Aubrey Grenville.
White, William Uttermare, M.C.
Wrighton, John Charles.

Associate to Associate Member

Barham, Alfred.
Barnes, Arthur.
Coldwell, David Kidd.
Hewitson, Maynard.
Hurworth, Harry.
Jagger, Hubert.
Prichard, Edgar James.
Roach, John Carlyle, B.E.
Savage, Joseph.
Steadman, Eric.
Warder, Stanley Bernard.

Graduate to Associate Member

Ankerson, William Albert, B.Sc.(Eng.).
Arnold, Sidney Roger.
Atkinson, Henry Harrison.
Baguley, Eric, B.Sc.Tech.
Bailey, Albert.

Graduate to Associate Member—continued.

Barrass, George Smith, B.Sc.(Eng.).
Beavis, Cuthbert John.
Behrens, Teodoro Adolfo, B.Sc.
Bellchambers, Harold Edgar.
Binns, Arthur William, B.Sc.(Eng.).
Boullen, Harold Godfrey, B.Sc.Tech.
Brett, Edward James.
Browning, Jeffrey Bellingham.
Buck, Charles Leslie F.
Bullard, Henry Joseph W.
Carrasco, Joseph, B.Sc. (Eng.).
Carter, Cecil John, B.A.
Clarence, Walter Anthony.
Clarkson, Thomas Reynolds, B.Sc.
Close, Charles John.
Clouston, Charles Edward.
Coates, William Henry, R. A., B.Sc.
Cotsworth, Walter Manning.
Datta, Manoranjan, M.Sc. Tech.
Day, Benjamin Lionel, B.Sc.(Eng.).
Dewan, Hargobind, B.Sc. (Eng.).
Dobbie, Leonard Graham, M.E.
Douglas, Cecil Stuart, B.Sc.
Edwards, Henry John.
Fareham, John.
Fletcher, Frank Whitehead
Fuad, Ibrahim.
Garner, Raymond Hubert, B.Sc.(Eng.).
Gash, John Edward.
Gilbert-Carter, John Codman, B.A.
Glanister, Charles William.
Greenlees, Frank Millar, B.Sc.
Gullan, Archibald Gordon, B.Sc.(Eng.), M.Sc.
Gupta, Chunni Lal, B.Sc. Tech.
Guthrie, Andrew.
Hall, Leonard Bruce.
Hall, William Garrow E.
Hamilton, Ivan Finlay C., B.E.
Harnden, Arthur Baker.
Hegazy, Hamed Mahmoud.
Hetherington, Harry Reid.
Hughes, George Ernest.
Hughes, James Robinson.
Jack, Charles Robertson, B.Sc.
Jackson, George Edwin.
Jacobs, Paul Geoffrey.
Jenkins, John William.
Johnson, George Ronald.
Johnston, Eric Francis.
Joyce, Richard Charles W.
Lancaster, John Bretland, B.Sc.
Lironi, Thomas Victor.
Lofthouse, Wilson Oswald.
Low, William Kemp, B.Sc.
McGill, John Stirling.
McInnes, Richard Edward, B.E.
Mackenzie, Eric Bruce, B.E.
Maharaja, Shantilal Sakarlal.
Marrian, Edward John M.
Moffatt, John James.
Morley, James Edwin.
Nelson, Humphrey Gordon.
Oliver, Gerald Arthur.
Parkinson, Hezekiah Bagot, B.Sc.
Paton, James Steele P., B.Sc.
Peiris, Seymour Wilfred, B.Sc.(Eng.).
Pember, Geoffrey, B.Sc. (Eng.).
Penney, Arthur Edward.
Pike, Cyril William.
Pollard, Stanley Metcalfe.
Potts, Frank, M.Eng.
Piper, Desmond Bamber.
Probert, Gilbert Ambrose.
Quayle, Joshua Creer, M.Eng.
Ravno, Albert.
Richards, Leslie Stephen.
Robertson, Ernest James, B.Sc.Tech.
Rogers, Bernard Henry G.
Rogers, Francis Gordan.
Rowe, Ernest George, M.Sc.
Scott, Henry William.
Shreeve, Alfred George.
Shrivastava, Hari Narayanlal, B.Sc.
Silverman, David.
Smith, Thomas Alexander, B.Sc.(Eng.).
Somasuntharam, George Devadason, B.Sc.
Spence, James Allan, B.Sc.
Taylor, Hugh Leake.

Graduate to Associate Member—continued.

Thomas, Geoffrey Bolton, B.Sc.(Eng.).
Thorn, Jack Gane.
Thorneycroft, William Henry, B.Sc.(Eng.).
Townshend, Alfred George, B.Eng.
Trigg, Arthur, B.Sc.
Tyrer, Alan Richard.
van Meeteren, Edward Henry.
Wade-Cooper, Frederick.
Wansbrough, Aubrey Kenwyn, B.E.
Warner, Ernest John, B.Sc.
Westwood, Edgar Fred, M.Eng.
Winder, Albert Edward.
Worthing, Robert Greenhill.
Young, Cyril Edward M.

The following transfers were also effected by the Council at their meeting held on the 20th October:—

Student to Graduate

Agnew, William Roy.
Aitken, Robert Muirhead.
Alagaratnam, Candiah.
Alesworth, Frederick Richard.
Allen, Harry Goodger, B.Sc.
Assisi, Jayakody Don Francis.
Baggott, Albert Jeffries.
Baker, Matthew William, B.Eng.
Bakeroff, Habib Khamsi, B.Sc.
Bambery, Colin McIntosh.
Barfield, Reginald Thomas.
Barrett, Arthur Crabtree.
Barry, Dennis George C.
Bastin, Douglas James.
Bates, Arthur William.
Bateson, Alan.
Bayes, Geoffrey Santon.
Bell-Francis, Trevor.
Berge, Morris.
Bhatia, Manmohan Singh.
Blake, Kenneth, B.Sc.
Brook, Edric Raymond.
Buck, James.
Burgess, Alfred Gibbon.
Burra, James Patrick M.
Cartwright, Jack.
Chandler, Robert Walter.
Clark, Gilbert.
Cloke, Ralph.
Cook, William Percy.
Corradi, Angelo, B.Sc. Tech.
Cotterell, Joseph.
Cox, Alan Henry.
Craske, Maurince Allan.
Darby, William Ernest.
Dark, Cyril Montague.
Darling, John.
Dowsett, Leslie Charles W.
Duerdoth, Winston Theodore.
Dukes, Frederick Ernest.
Dunsford, Ernest Graham.
Farrall, Robert.
Fawcett, Charles Henry.
Ferguson, Ian Andrew.
Fisher, Cyril Kenneth.
Fleming, John Stuart, B.Sc.
Foulkes, Christopher Henry.
Gange, Hedley Gordon.
Garrett, Maurice Arthur.
Graham, Frank.
Griffith, George William S.
Grimley, William Kenneth.
Guest, Raymond Arthur, B.Sc.(Eng.).
Habicht, Ronald Charles.
Halewood, William, B.Eng.
Hampton, Arthur Edward.
Hards, John.
Havenith, Fernand Joaquim.
Heath, James Henry.
Hewlett, Stanley James.
Hindle, Harold, B.Sc.Tech.
Hollingworth, Stephen Ian.
Hopkinson, Arthur.
Houghton, Edwin, B.Sc. Tech.
Hughes, Raymond Ernest.
Hunt, Alan William J.
Hunt, Thomas William, B.Eng.
Isaac, John Edward.
Jackson, Charles Frederick.
James, Charles Kenneth, B.Sc.
James, George Anthony.
Johnston, Frank.
Karanjia, Pheroze Behram.
Kay, Sydney Pitfield, B.Sc. (Eng.).
Kharas, Cursetji Gustadji, B.Sc.(Eng.).
Kraal, Edmund George R.
Langley, Richard William.

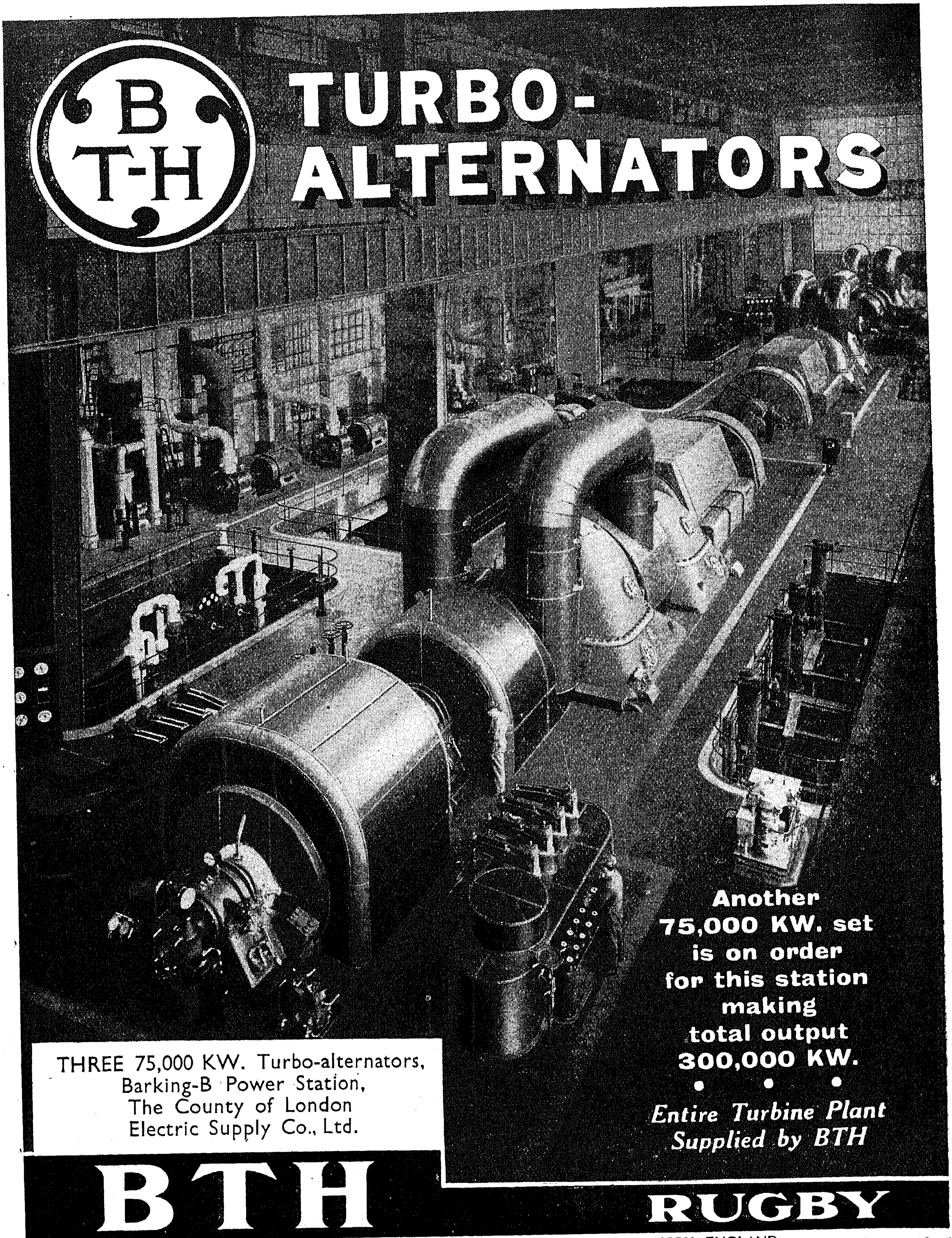
Student to Graduate—continued.

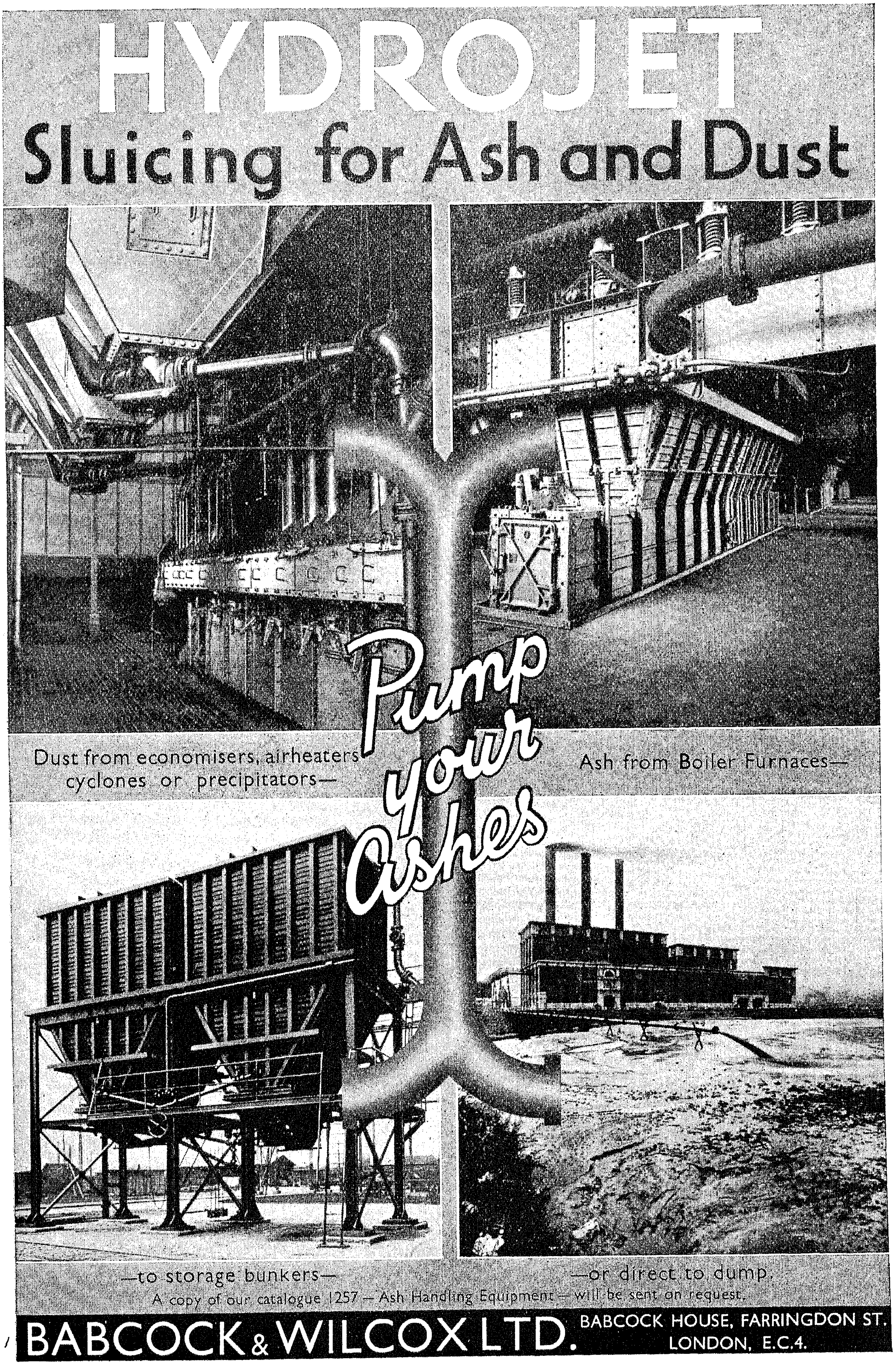
Leigh, Ronald Craig, B.Sc. (Eng.).
Leong, Sik Aun, B.Sc. (Eng.).
Linsell, Russell Frederick, B.Sc.
Lord, William George.
Lynch, George Daniel.
McClelland, John Dermot, B.Sc.
Mansfield, Reginald Frederick.
Martin, Richard Peter G.
Meek, George Gilbert.
Meerza, Harold James, B.Sc.
Miller, Jack.
Mitchell, Maurice.
Nuttall, David.
Osborn, Peter Digby, B.Sc. (Eng.).
Outram, Lionel John, B.Sc.
Oxford, Cecil George H., B.Sc.
Pagdin, Edward Houldin.
Partington, George Earnshaw, B.Sc.Tech.
Patrick, Robert James.
Pearce, Howard Raymond, B.Sc.Tech.
Peck, Francis George.
Penley, William Henry, B.Eng.
Peretz, Louis.
Perkins, Albert John.
Phillips, Alban William.
Pilling, Thomas, B.Sc. Tech.
Pollard, Leslie Charles.
Raban, Francis William N.
Rice, Joseph, B.Eng.
Robinson, Thomas Philip.
Rustin, Maurice Edward.
Rutter, George Willis.
Ryness, Joseph Woolfe.
Saner, John.
Schultz, Edward Arthur, B.E.
Sellar, James Alexander, B.Sc.(Eng.).
Shelley, John Paul, B.E.
Siddappa, Byranna.
Silvester, Leslie Frederick.
Smith, Herbert Samuel, B.Sc.
Smithson, Noel William, B.Sc.(Eng.).
Stephenson, George William.
Stephenson, Thomas George
Story, Edward.
Stott, George.
Subrahmanyam, P.Ch.
Thomas, Eric Lloyd, B.Sc.
Thorpe, Eric.
Travis, Leonard Kirkbride.
Varcoe, Kingsley John.
Walker, Dennis Ford, B.Sc. (Eng.).
Ward, Jack.
Warden, Frederick William, B.Sc.
Waugh, George Frederick.
Weaire, Reginald Frederick.
Webb, Denis Chaundy.
Weil, Goetz Joachim D.
Whaley, Norman Sheffield.
Wiffen, Cecil Sidney.
Wilder, Dion Dealtry, B.Sc. (Eng.).
Wilson, William John, B.Sc.
Wincott, Leslie Moreland.
Wooller, Maurice Philip.
Workman, Albert Henry.
Wylie, John Howard.
Zuckerman, Narcisse, B.Sc.

The following transfers were also effected by the Council at their meeting held on the 1st December:—

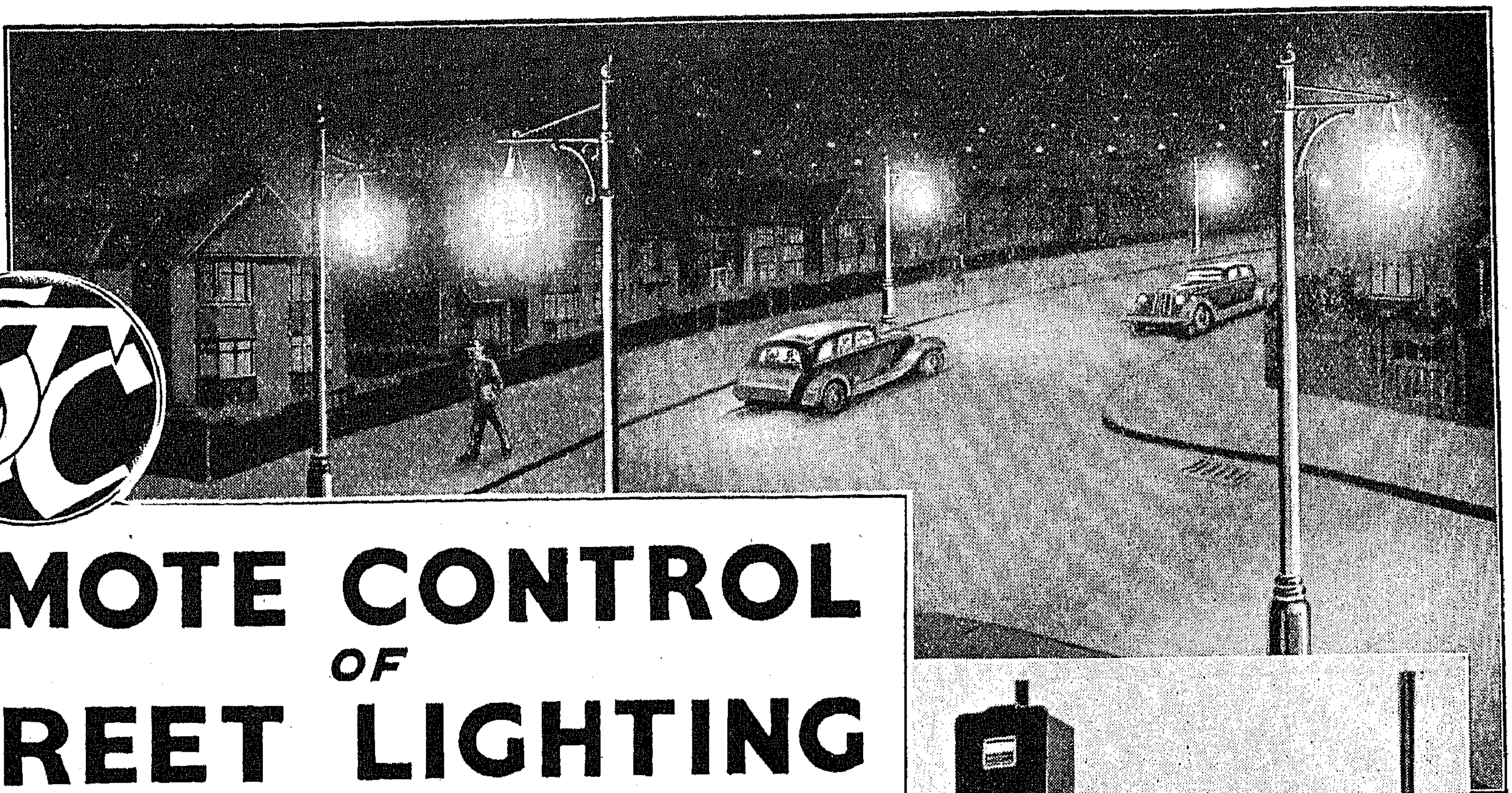
Student to Graduate

Alderson, Robert.
Astill, Roy Preston.
Bate, Leslie Arnold E.
Branton, John Sheard.
Browning, Roy William, B.Sc.(Eng.).
Carding, Joseph Thom, B.Sc.
Cheshire, William Thom A.
Crawshaw, Angus Grant.
Donald, William Horace.
Forty, Albert John, B.A.
Foy, Ernest William H.
Freeland, James Archibald D.
Gentles, Ernest Robert.
Gilby, Kenneth Barrington, B.E.
Hawkins, David L.
Hutty, William Desmond, B.Sc.
Jones, Horace Frederick B.Sc.(Eng.).
Kyle, William Albert, B.Sc.
Lewin, Valentine Arthur.
McKie, James Domville.
Maddams, Leo Edwin.
Manning, Cyril Edwin.
Martindale, Robinson George, B.Sc., M.Sc.
Meher-Homji, Behram Ardeshir, B.Sc.
Muret, Douglas Adrian, B.Sc.(Eng.).
Prior, Hector Thomas, B.Sc.(Eng.).
Porter, John Howard.
Rae, William James S.
Rivett, John Colin, B.Sc. (Eng.).
Robertson, Alfred Peter.
Robertson, George Pearson.
Semken, Philip.
Sharp, Eric Samuel.
Stockell, Cyril John, B.Sc. (Eng.).
Threlfall, Andrew James C.
Tidman, Walter Douglas.
Unitt, John Leslie.
Watt, Thomas John.
Wood, Edward Kemp.
Young, Arthur Harry.

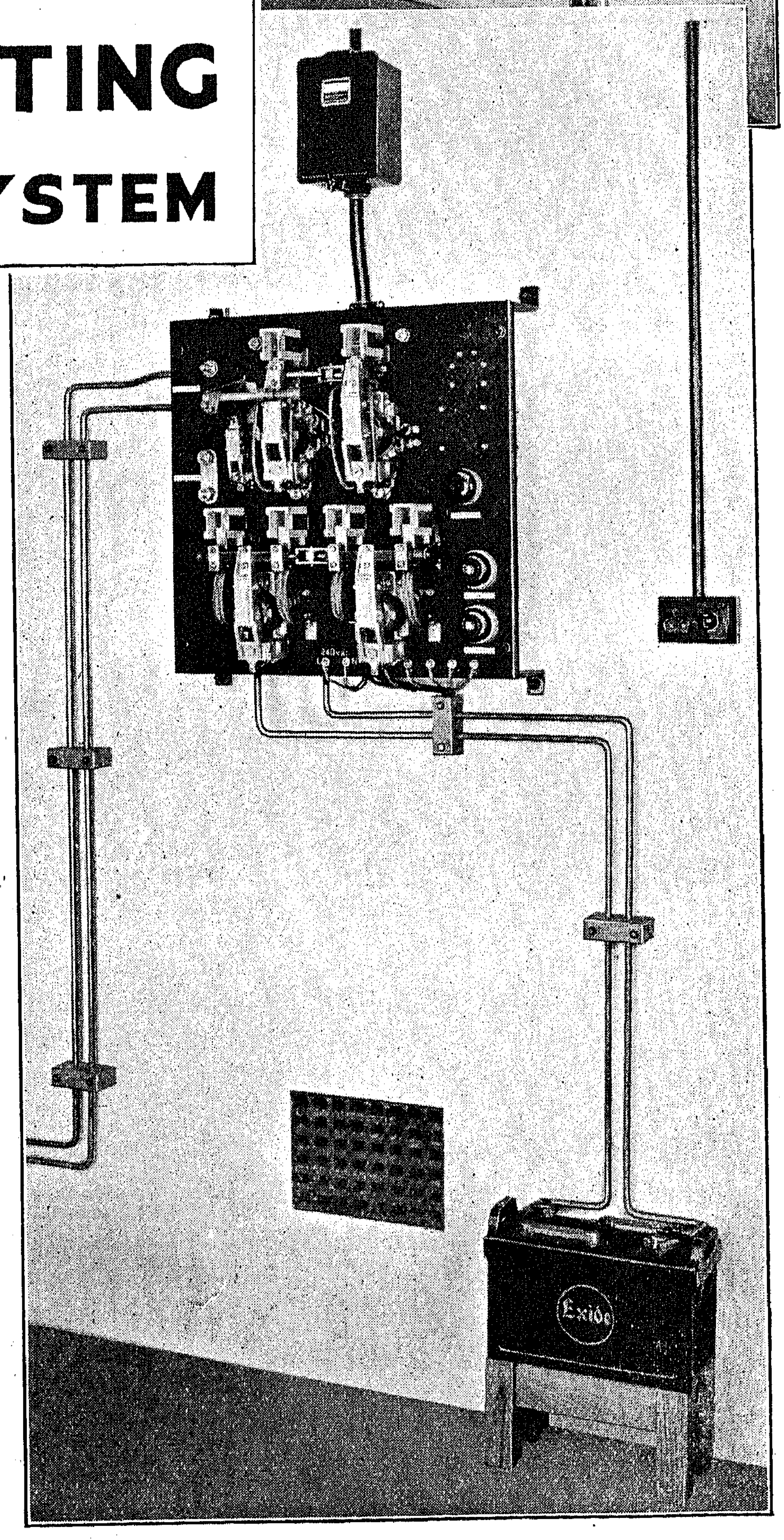

B T-H
TURBO-
ALTERNATORS
Another
75,000 KW. set
is on order
for this station
making
total output
300,000 KW.
Entire Turbine Plant
Supplied by BTH
THREE 75,000 KW. Turbo-alternators,
Barking-B Power Station,
The County of London
Electric Supply Co., Ltd.
BTH
RUGBY


HYDROJET
Sluicing for Ash and Dust
Pump your Ashes
Dust from economisers, airheaters cyclones or precipitators—
Ash from Boiler Furnaces—
—to storage bunkers—
—or direct to dump.
A copy of our catalogue 1257 — Ash Handling Equipment — will be sent on request.
BABCOCK & WILCOX LTD.
BABCOCK HOUSE, FARRINGDON ST. LONDON, E.C.4.

No. 1 of a series



REMOTE CONTROL
OF
STREET LIGHTING
AND
MULTI-SERVICE SYSTEM



ECONOMICAL centralised control of street lighting is the basis of the S.T.C. Multi-Service System. When to this is added the fact that the system can be so easily extended to provide control of restricted tariff service and A.R.P. warning and calling facilities, the ever-increasing popularity of this proved and approved system is obvious.

Its salient features are:

Reliability.

Centralised control with the ability to decentralise control immediately this becomes necessary during an emergency.

Freedom from false operation by external influences, such as lightning or power surges, etc.

Freedom from interference due to high frequency harmonics or induced ripple currents.

LOW INITIAL COST.

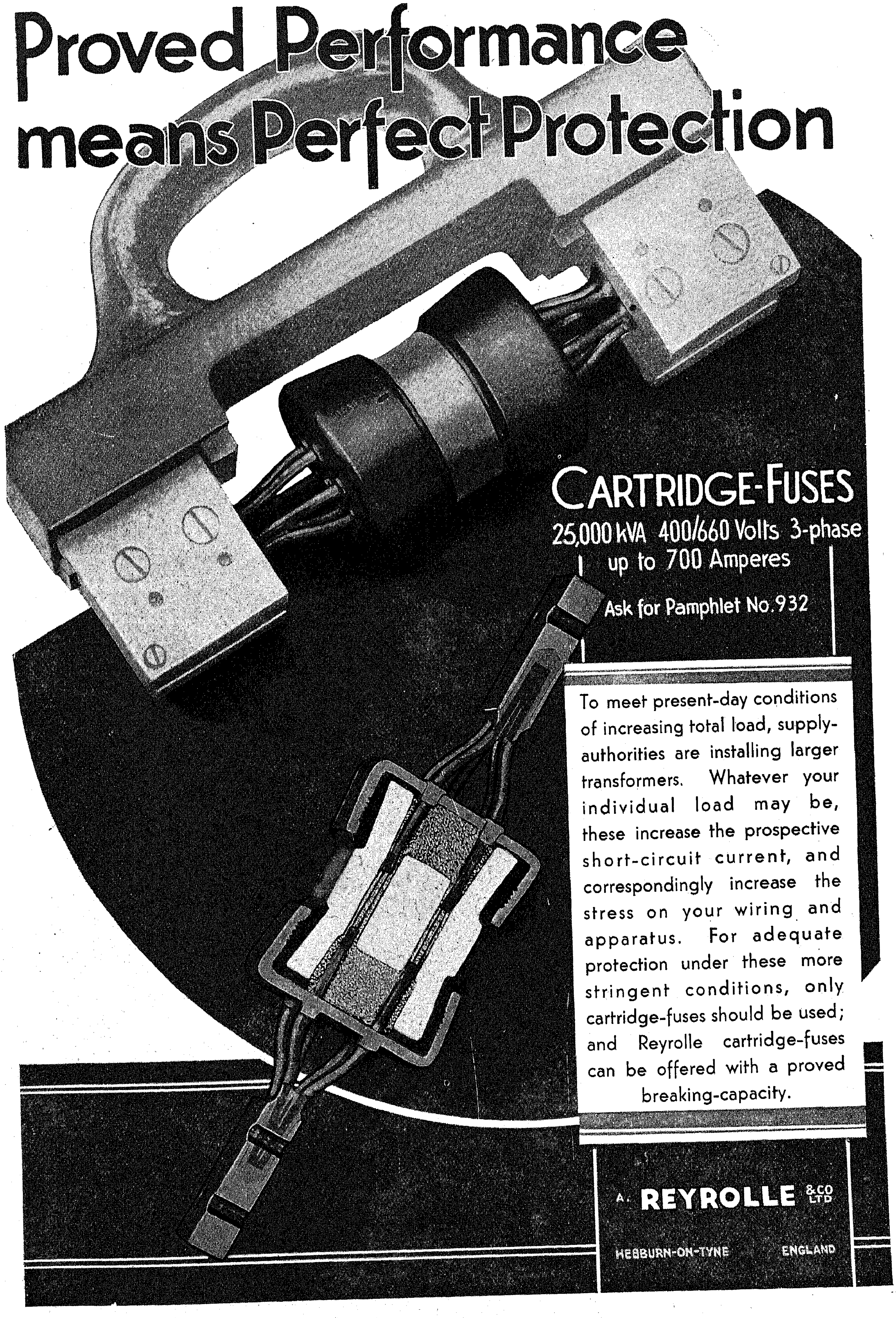
The illustration shows a Sub-station Biasing Panel and Battery.

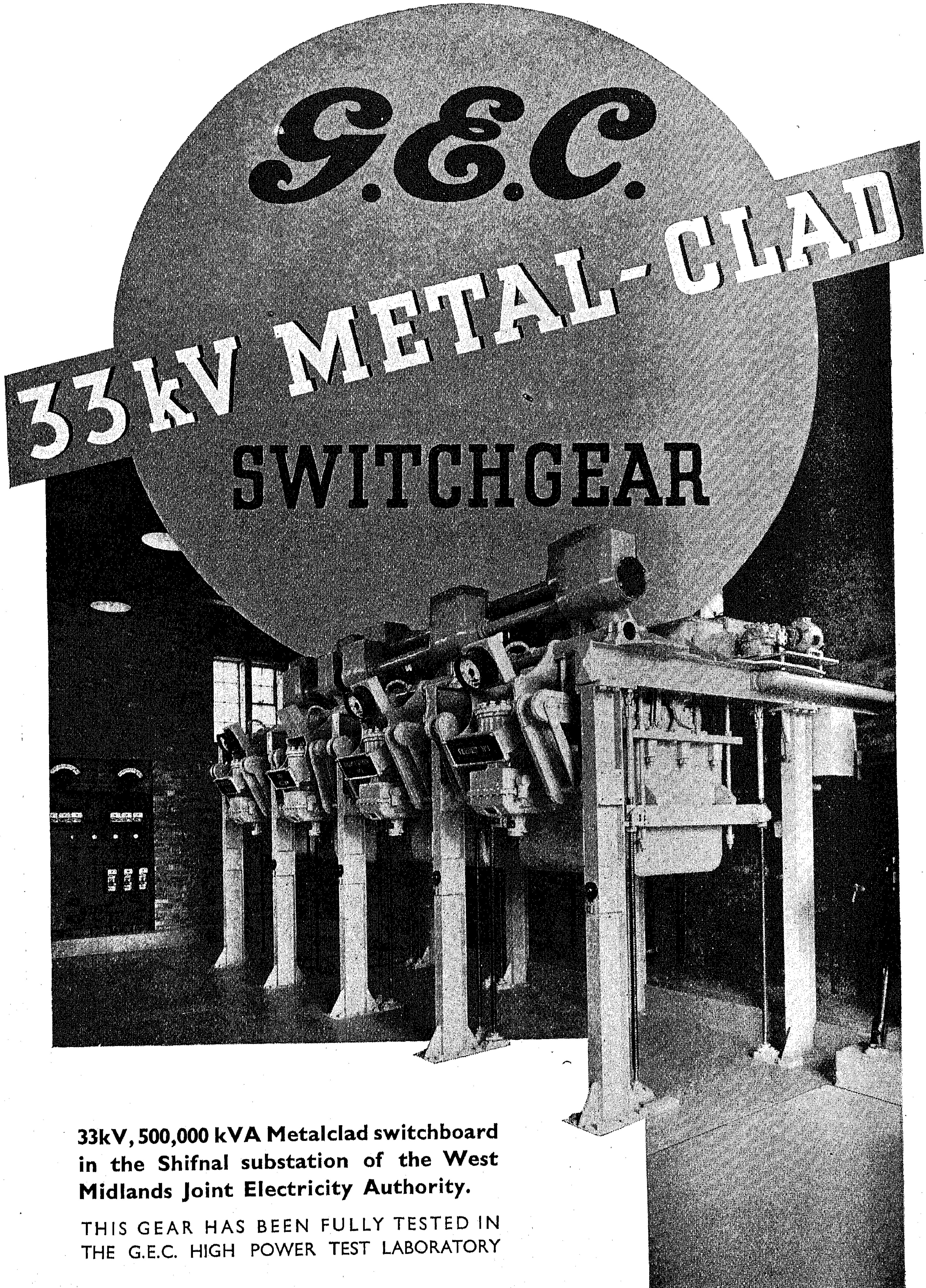
Our illustrated brochure SRC 1102/1 will be sent upon request.

Standard Telephones and Cables Limited

New Southgate, London, N. 11.

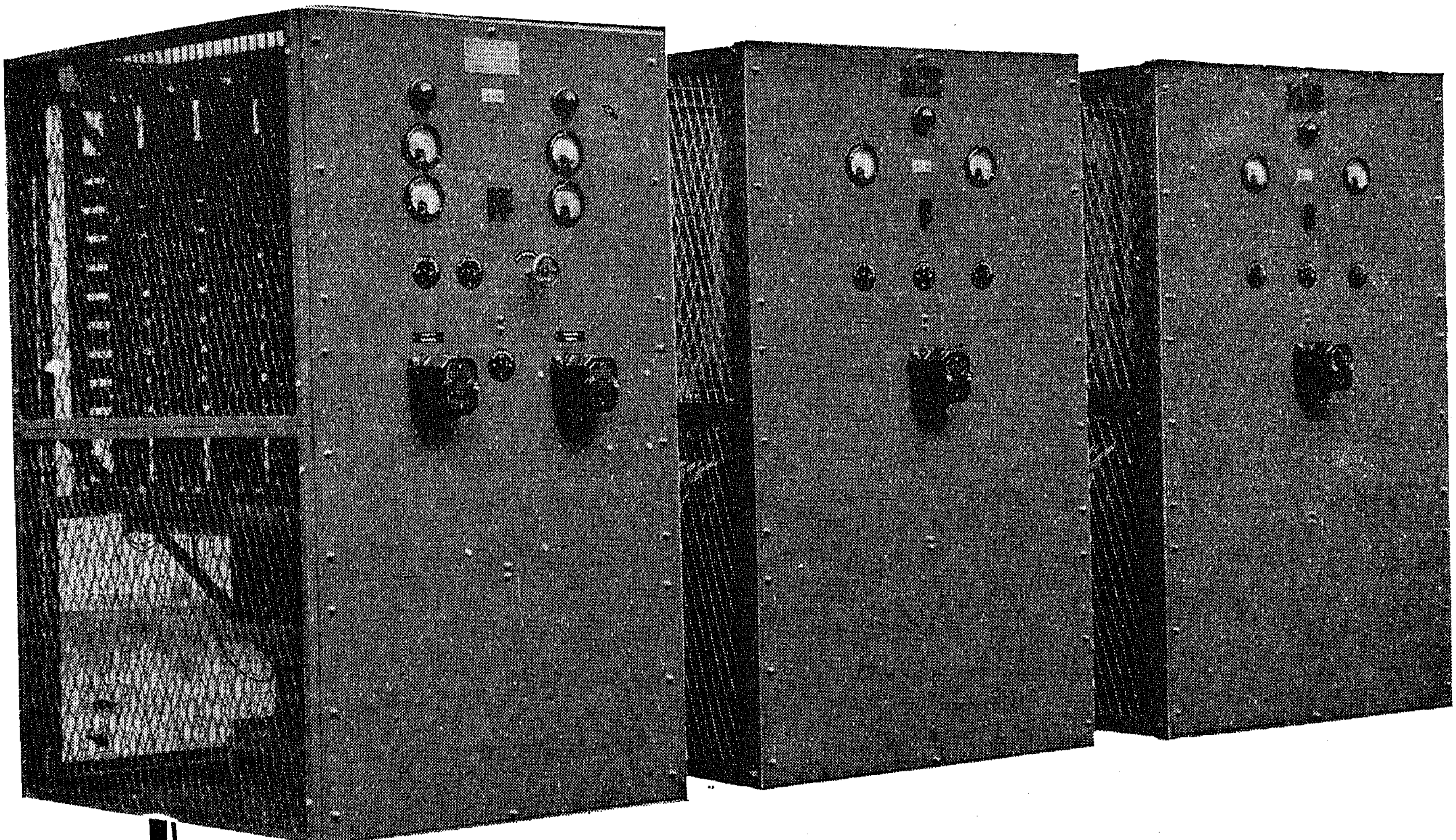
Telephone: Enterprise 1234


Proved Performance
means Perfect Protection
CARTRIDGE-FUSES
25,000 kVA 400/660 Volts 3-phase
up to 700 Amperes
Ask for Pamphlet No. 932
To meet present-day conditions of increasing total load, supply-authorities are installing larger transformers. Whatever your individual load may be, these increase the prospective short-circuit current, and correspondingly increase the stress on your wiring and apparatus. For adequate protection under these more stringent conditions, only cartridge-fuses should be used; and Reyrolle cartridge-fuses can be offered with a proved breaking-capacity.
A. REYROLLE & CO LTD
HEBBURN-ON-TYNE ENGLAND



33kV, 500,000 kVA Metalclad switchboard in the Shifnal substation of the West Midlands Joint Electricity Authority.

THIS GEAR HAS BEEN FULLY TESTED IN THE G.E.C. HIGH POWER TEST LABORATORY



NOTE

ADVERTISEMENT copy and blocks should reach the authorized agents, Industrial Publicity Service, Ltd., 4 Red Lion Court, Fleet Street, E.C. 4 (Telephone: Central 8614), not later than the 20th of each month for publication the following month.

Inquiries regarding space in this section of the Journal should be addressed to the Manager.

LIST OF ADVERTISERS IN THIS ISSUE

NORTH-WESTERN CENTRE.

Chairman.—W. FENNELL.
Hon. Secretary.—L. H. A. CARR, M.Sc.Tech., " Oakleigh," Cambridge Road, Hale, Altrincham, Cheshire.

SCOTTISH CENTRE.

Chairman.—W. J. COOPER.
Hon. Secretary.—R. B. MITCHELL, 154, West George Street, Glasgow, C.2.
Hon. Assist. Secretary.—H. V. HENNIKER, 172, Craigleith Road, Edinburgh.

Dundee Sub-Centre.

Chairman.—G. F. MOORE, B.Sc.
Hon. Secretary.—P. PHILIP, c/o Electricity Supply Dept., Dudhope Crescent Road, Dundee.

SOUTH MIDLAND CENTRE.

Chairman.—H. FAULKNER, B.Sc.
Hon. Secretary.—R. H. RAWLL, 65, New Street, Birmingham.

East Midland Sub-Centre.

Chairman.—T. ROWLAND.
Hon. Secretary.—J. F. DRIVER, Brighton House, Herrick Road, Loughborough.

WESTERN CENTRE.

Chairman.—H. S. ELLIS.
Hon. Secretary.—G. L. COVENTON, 126, London Road, Gloucester.

Devon and Cornwall Sub-Centre.

Chairman.—H. MIDGLEY, M.Sc.
Hon. Secretary.—F. C. ISAAC, Council Offices, Plympton, South Devon.

West Wales (Swansea) Sub-Centre.

Chairman.—J. E. DAWTRY.
Hon. Secretary.—R. RICHARDS, 78, Glanbrydan Avenue, Swansea.

Hampshire Sub-Centre (directly under the Council).

Chairman.—W. S. LONSDALE.
Hon. Secretary.—A. G. HISCOCK, c/o City of Portsmouth Electricity Undertaking, 111, High Street, Portsmouth, Hants.

Northern Ireland Sub-Centre (directly under the Council).

Chairman.—F. JOHNSTON.
Hon. Secretary.—J. McCANDLESS, M.Sc., Burn Brae, Strangford Avenue, Belfast.

INFORMAL MEETINGS.

Chairman of Committee.—P. P. WHEELWRIGHT.

METER AND INSTRUMENT SECTION.

Chairman.—CAPTAIN B. S. COHEN, O.B.E.

OVERSEAS CO[illegible]

AUSTRALIA.

New South Wales.

Chairman.—V. L. MOLLOY.
Hon. Secretary.—W. J. McCALLION, M.C., c/o Electrical Engineers Branch, Dept. of Public Works, Sydney.

Queensland.

Chairman and Hon. Secretary.—J. S. JUST, c/o P.O. Box 1067N, G.P.O., Brisbane.

South Australia.

Chairman and Hon. Secretary.—F. W. H. WHEADON, Kelvin Building, North Terrace, Adelaide.

Victoria and Tasmania.

Chairman and Hon. Secretary.—H. R. HARPER, 22–32, William Street, Melbourne.

Western Australia.

Chairman.—J. R. W. GARDAM.
Hon. Secretary.—A. E. LAMBERT, B.E., 35, The Esplanade, South Perth.

CEYLON.

Chairman.—MAJOR C. H. BRAZEL, M.C.
Hon. Secretary.—D. P. BENNETT, c/o Messrs. Walker Sons & Co., Ltd., Colombo.

Cha[illegible]
Hon. [illegible]
Post Fort, Bombay.

Calcutta.

Chairman.—F. T. HOMAN.
Hon. Secretary.—D. H. P. HENDERSON, c/o Calcutta Electric Supply Corporation, Post Box 304, Calcutta.

Lahore.

Chairman.—V. F. CRITCHLEY.
Hon. Secretary.—J. C. BROWN, c/o Associated Electrical Industries (India) Ltd., P.O. Box 146, Lahore.

Madras.

Chairman and Hon. Secretary.—E. J. B. GREENWOOD, Electricity Dept., P.W.D. Offices, Chepauk, Madras.

NEW ZEALAND.

Chairman.—F. T. M. KISSEL, B.Sc.
Hon. Secretary.—J. McDERMOTT, P.O. Box 749, Wellington, C.1.

SOUTH AFRICA.

Transvaal.

Chairman and Hon. Secretary.—W. ELSDON DEW, Box 4563, Johannesburg.

LOCAL HONORARY SECRETARIES ABROAD.

ARGENTINE: R. G. PARROTT, Tucuman 117, Buenos Aires.
CANADA: F. A. GABY, D.Sc., Vice-President, The British American Oil Co., Ltd., 14th Floor, Royal Bank Building, Toronto, Ontario.
CAPE, NATAL, AND RHODESIA: G. H. SWINGLER, City Electrical Engineer, Corporation Electricity Dept., Cape Town.
FRANCE: P. M. J. AILLERET, 20, Rue Hamelin, Paris (16e).
HOLLAND: A. E. R. COLLETTE, Heemskerckstraat, 30, The Hague.
INDIA: K. G. SILLAR, c/o Calcutta Electric Supply Corporation, Post Box 304, Calcutta.
ITALY: L. EMANUELI, Via Fabio Filzi, 21, Milan.
JAPAN: I. NAKAHARA, No. 40, Ichigaya Tanimachi, Ushigomeku, Tokio.
NEW SOUTH WALES: V. J. F. BRAIN, B.E., Chief Electrical Engineer, Department of Public Works, Bridge Street, Sydney.
NEW ZEALAND: J. McDERMOTT, P.O. Box 749, Wellington, C.1.
QUEENSLAND: J. S. JUST, c/o P.O. Box 1067N, G.P.O., Brisbane.
SOUTH AUSTRALIA: F. W. H. WHEADON, Kelvin Building, North Terrace, Adelaide.
TRANSVAAL: W. ELSDON DEW, Box 4563, Johannesburg.
UNITED STATES OF AMERICA: GANO DUNN, c/o The J. G. White Engineering Corporation, 80, Broad Street, New York, N.Y.
VICTORIA AND TASMANIA: H. R. HARPER, 22–32, William Street, Melbourne.
WESTERN AUSTRALIA: PROF. P. H. FRAENKEL, B.E., The University of Western Australia, Crawley, Perth.

STUDENTS' SECTIONS.

LONDON.

Chairman.—P. H. PETTIFOR.
Hon. Secretary.—A. H. YOUNG, "Park View," Alton Road, Roehampton, S.W.15.

NORTH-WESTERN.

Chairman.—R. NOONAN.
Hon. Secretary.—R. M. A. SMITH, Meter Engineering Dept., Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

SCOTTISH.

Chairman.—J. BROWN.
Hon. Secretary.—G. H. WIRE, c/o Mrs. Cormie, 8, Townhead Terrace, Paisley.

NORTH-EASTERN.

Chairman.—F. M. BRUCE.
Hon. Secretary.—J. A. STANFIELD, 44, Shipley Avenue, Milvain, Newcastle-on-Tyne.

MERSEY AND NORTH WALES (LIVERPOOL).

Chairman.—T. E. A. VERITY, B.Sc.Tech.
Hon. Secretary.—W. H. PENLEY, B.Eng., Laboratories of Applied Electricity, The University, Liverpool, 3.

SOUTH MIDLAND.

Chairman.—J. E. WOOLLASTON.
Hon. Secretary.—B. S. COPSON, 88, Reservoir Road, Olton, Birmingham.

NORTH MIDLAND.

Chairman.—A. H. MARSH.
Hon. Secretary.—G. H. WARNE, 6, Parkfield Road, Shipley, Yorkshire.

SHEFFIELD.

Chairman.—H. A. WAINWRIGHT, B.Eng.
Hon. Secretary.—C. C. BACON, Corporation Electricity Department, Commercial Street, Sheffield, 1.

BRISTOL.

Chairman.—W. H. SMALL.
Hon. Secretary.—J. W. DORRINTON, 20, Trelawney Road, Cotham, Bristol, 6.

LOCAL HON. TREASURERS OF THE FUND.

Irish Centre: T. J. MONAGHAN. *North-Eastern Centre:* N. CRESSWELL. *North Midland Centre:* R. M. LONGMAN. *Sheffield Sub-Centre:* W. E. BURNAND. *North-Western Centre:* T. E. HERBERT. *Mersey and North Wales (Liverpool) Centre:* A. C. LIVESEY. *Scottish Centre: (Glasgow)* A. LINDSAY; *(Edinburgh)* D. S. MUNRO. *Dundee Sub-Centre:* P. PHILIP. *South Midland Centre:* W. Y. ANDERSON. *Western Centre: (Bristol)* E. P. KNILL; *(Cardiff)* J. W. ELLIOTT. *Hampshire Sub-Centre:* W. P. CONLY, M.Sc.

PRINTED BY UNWIN BROTHERS LIMITED, LONDON AND WOKING